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Chicago: DWIGHT H. EARLY
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EDITORIALS

Neglects in Restraint of Trade

PERIODICALLY there is much ado about acts and combinations in restraint of trade, actual or alleged. A few big steals, numerous investigations, widespread misunderstanding of business, the ease of blaming others for our misfortunes and lack of prosperity, the psychological need of a tangible common enemy, and the ominous appearance of big business have combined to make it a popular bogey.

We probably do need some protection from the few individuals who would and could deliberately and by overt acts restrain trade for their benefit and at our expense. But even this protection can have a trade-restraining effect if it is carried to the point of forcing legitimate business to prove its innocence, at considerable trouble and expense which increases the cost and difficulty, and decreases the incentives, of doing business.

One of the chief complaints against monopolies is that they restrain trade by maintaining artificially high prices, not justified by costs. But the operation of economic law is such that the trade-restraining effect of high prices will be the same whether they are caused by illegal monopolistic connivance, low production efficiency and high costs, high taxes, waste, or other cost items. Failure to exert every reasonable human effort to improve production efficiency and reduce costs is neglect in restraint of trade.

Probably the most flagrant and inexcusable neglect in restraint of trade is the failure of many producers to utilize fully proven and readily available methods of reducing costs. Another common neglect is that of not using science and engineering as fully as possible to work out new ways to reduce costs and to develop new and improved products. Still another is waste of exhaustible natural resources, which can only mean restraint of future trade. And, conversely, there is waste in failure to make full advantageous use of such inexhaustible natural resources as sunlight, air, organic life, and in some places, water.

All of this is manifestation of the common human failure to fully exercise our inherent individual capacities. Trade is restrained by the fact that we do not work or live as well as we know how, and that we do not learn more as rapidly as we could. Small businesses and individuals, as well as large corporations; manufacturers, farmers, and transportation and other services; science and the professions, all are guilty. The production efficiency of a few years ago now looks pitifully poor. If neglects in restraint of trade were punishable as criminal negligence, we would all be condemned for today's practices by tomorrow's improvements.

It seems likely that, because of their commonness, neglects have a far greater aggregate trade restraining effect than overt acts. And the individual can do most to free trade from restraint, with greatest direct benefit to himself and incidental benefit to society, by correcting his own neglects. A part of the remedy, for many people and industries, could be realized by more generous employment, support, and encouragement of engineering help toward increasing productivity and production efficiency. And for engineers it might be realized by more diligent practice of their profession. Unless we are fatalists or beggars we must depend largely on our own attitudes, acts, and influences for improvement of the conditions under which we live and work, and look to our own neglects, as well as to outside influences, for the causes of our failures.

Visual Study of Rapid Motions

HOUDINI and many a lesser prestidigitator have capitalized on the fact that "the hand is quicker than the eye." Research is reversing the advantage by enabling the eye, with the aid of high-speed photography and its adjunct, stroboscopy, to follow any motion of the hand. What is more important, the eye, with these aids, can now see shapes, position relationships, and transient effects in the rapid motions of certain natural phenomena and many mechanical devices and processes. The eye is now quicker than complicated theoretical analysis in showing what happens in a lot of motions by which engineering design may succeed or fail.

The paper by J. Otis Laws, entitled "Studies in Raindrops and Erosion," in AGRICULTURAL ENGINEERING for November, shows high-speed still photographs of raindrop shapes and effects. This suggests that it might also be extremely interesting and profitable to see what actually happens in some other natural phenomena about which agricultural engineers are supposed to do something, and in the operation of equipment produced or in process of development for farm use.

How about some candid camera shots of a mower knife section in the very act of shearing through a stem of alfalfa? Or the internal workings of a combine cylinder?

A visual audit of experimental and commercial machine part motions, vibrations, distortions, and fits in high-speed operation might start a rogues' gallery of power thieves.

For the musically inclined engineer, the symphony of functional sounds and the disharmonies of poor operation could be pictured in relation to their causes as an auditory aid to mechanical trouble-shooting.

As a sporting event of possible engineering significance we would like to see slow-motion movies and the photo-finish of a race between particles in a turbulent stream of air or liquid.

Another transient phenomenon which may now be studied to much better advantage with these aids is impact. In terms of a sequence of a thousand or more phases, what does happen in the fraction of a second when and after the head of a hammer hits the head of a nail? Or in other instances of impact of probably greater importance from the standpoint of indicating changes in design or practice?

We would like to see the artistry of motion initiated in various blasting applications—as pictured at several thousand exposures per second.

Some day some agricultural engineer may be at the right place at the right time, with the right equipment, to record the tragic drama of a windstorm tearing apart a building. The screen reenactment in slow-motion would cast some broad hints as to desirable construction practices.

In visual effect, the stroboscope is a microscope of the fourth dimension. Synchronized with a high-speed motion picture camera it can take thousands of pictures of the events of one second, and the time interval magnified in reshowing to a matter of minutes or hours, a range with which the human eye and mind can work. It can show in individual pictures still views of conditions which in their very nature exist only in rapid motion. With or without the aid of photographic equipment it can show rapidly revolving or reciprocating parts as if standing still or moving slowly. The cost is not prohibitive as laboratory equipment goes. When some agricultural engineering laboratory gets started using it, we expect to see some really interesting and instructive movies, and some resulting progress in design and performance of farm structural and mechanical equipment.

AGRICULTURAL ENGINEERING

VOLUME 21 DECEMBER 1940 NUMBER 12

Results of Investigations of Milk Cooling

By June Roberts and Geo. H. Larson

MEMBER A.S.A.E. JUNIOR MEMBER A.S.A.E.

BACTERIA growth in milk is a function of time and temperature. Fig. 2 shows the effect of temperature and time upon bacteria growth. The number of bacteria are plotted on a logarithmic scale. Fig. 3 shows the effect of the delay in cooling milk upon the bacteria growth. From these two figures the importance of refrigeration upon the growth of bacteria is evident.

In a survey made during the summer of 1939, it was found that practically all the milksheds in Kansas were operating under the United States Public Health Service standard milk ordinance which was approved by the Kansas State Board of Health. The temperature requirements are that grade A raw milk must be cooled to 50 F (degrees Fahrenheit) or less within one hour after completion of milking and maintained at that temperature until delivery, and grade B raw milk which is to be pasteurized must be cooled to 70 F within two hours after completion of milking and maintained at that temperature until delivery.

There are a few milksheds in Kansas which have to meet a more rigid cooling requirement. One large pasteurizing plant requires that grade B milk meet grade A cooling requirements. Milk cooling requirements in many sections of Kansas are becoming more rigid. Customers are demanding a higher quality milk. The problem of cooling milk to meet the temperature requirements has made it necessary for many dairymen to purchase mechanical refrigerators. Many dairymen have asked, "What does it cost to cool milk and how does the cost vary with different methods being used?"

In an effort to answer these questions, a project was started July 1, 1939, by the department of agricultural engineering of Kansas State College, cooperating with the department of dairy husbandry and the Kansas Committee on the Relation of Electricity to Agriculture. The general objectives of the project were (1) to determine the present practices in several milksheds in Kansas, (2) to determine the cost, efficiency, and convenience of cooling milk by the important methods now used, and (3) to study new methods which showed promise in the preliminary survey.

The information used in this study was obtained as follows:

1 A preliminary survey was prepared on the present practices of milk production and on the equipment now used. The milk inspectors at Kansas City, Lawrence, Topeka, Emporia, Wichita, and Manhattan were visited. From these inspectors a report on 1,144 individual producers was secured.

2 A questionnaire was made out to determine the costs and present practices from the individual dairymen. Replies from 30 producers were secured by mail and 30 replies were obtained by personal interview.

3 Field data on rates of cooling, costs, and present practices were obtained from 28 farms.

4 Laboratory tests were made on four well-known milk coolers to check the field data and to study other factors which did not lend themselves for field study.

Survey Data. From the data secured by survey it was found from the 1,144 graded producers that 25 per cent were grade A, 74 per cent were grade B, and 1 per cent grades C and D. Of these 1,144 producers, 67 per cent had electricity available, while only 20 per cent used mechanical milkers. The survey shows that 24 per cent of the 1,144 producers did not cool their milk, 40 per cent used well water, 12 per cent used ice, and 24 per cent used mechanical coolers. Of this 24 per cent who had mechanical coolers, 28 per cent used wet storage, 48 per cent the dry box, and 24 per cent the dry walk-in box. The mean well water temperature varied from 56 to 64 F, and the mean cost of ice was 29.9 cents per hundred.

Results from Questionnaire. From the questionnaire received from 60 dairymen, thirty-six were grade A producers and twenty-four were grade B producers. Seventy per cent of these dairymen had electricity available, with an average monthly electric consumption of 564 kw-hr. Forty-five per cent used mechanical milkers and 66 per cent used mechanical coolers, of which 44 per cent were wet storage, 26 per cent walk-in, 30 per cent dry box; 21 per cent of the 60 dairymen cooled milk by well water, and 13 per cent used ice.

The average ice consumption for July and August, 1939, for four grade A producers was 107 lb of ice per 100 lb of milk cooled, and the average for the grade B producers for the same period was 41 lb per 100 lb of milk.

Field and Laboratory Data. In the field and laboratory study temperatures were measured by dairy thermometers, recording thermometers, and by thermocouples. Fig. 1 shows a line diagram of the thermocouple locations for studying the rate of cooling. Thermocouple A was used in the laboratory study and thermocouple B was used in the

Presented before the Rural Electric Division at the annual meeting of the American Society of Agricultural Engineers, at State College, Pa., June 17, 1940. (Contribution No. 96 of the agricultural engineering department, Kansas State College.) Authors: Respectively, investigator, Washington C. R. E. A. (formerly instructor in agricultural engineering, Kansas State College), and assistant in agricultural engineering, University of Wisconsin (formerly graduate assistant in agricultural engineering, Kansas State College).

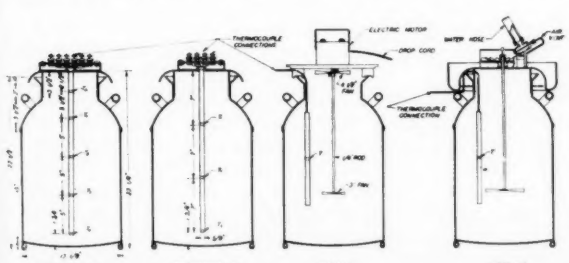

FIG. 1. THERMOCOUPLE ARRANGEMENTS AND AGITATING EQUIPMENT TO INCREASE RATE OF COOLING MILK IN CANS

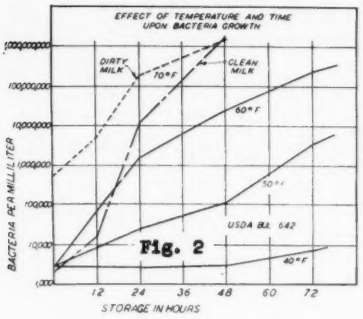

Fig. 2

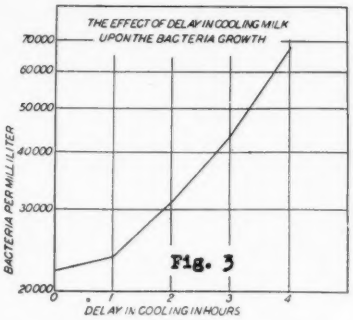

Fig. 3

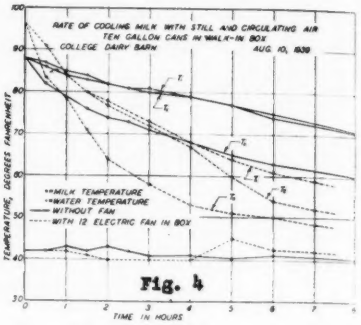

Fig. 4

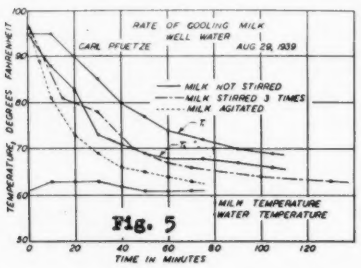

Fig. 5

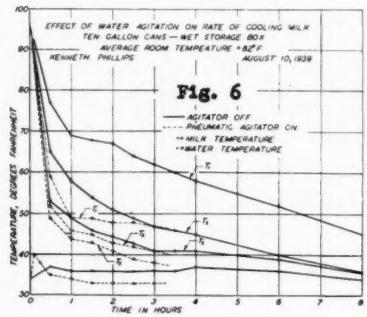

Fig. 6

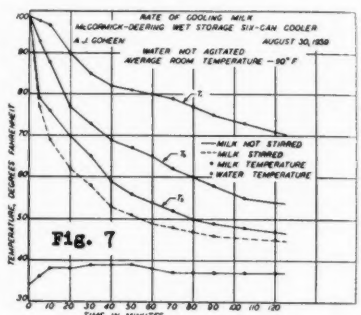

Fig. 7

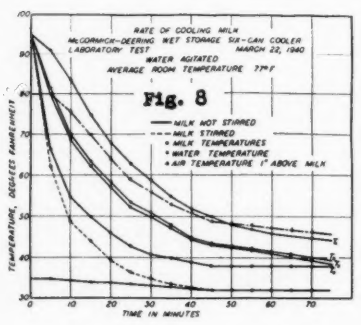

Fig. 8

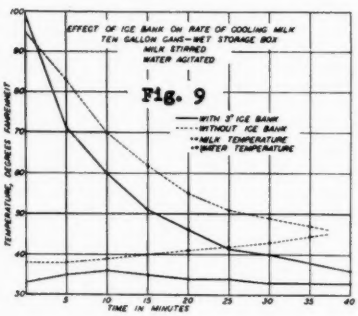

Fig. 9

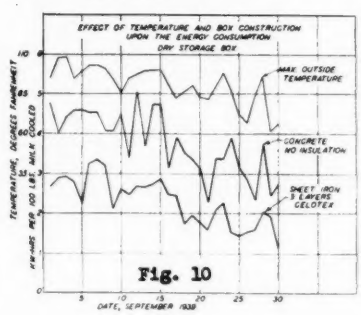
EFFECT OF TEMPERATURE AND BOX CONSTRUCTION UPON THE ENERGY CONSUMPTION
DRY STORAGE BOX
MAX. OUTSIDE TEMPERATURE
CONCRETE NO INSULATION
SHEET IRON 3 LAYERS CELOTEX
TEMPERATURE, DEGREES FAHRENHEIT
DATE, SEPTEMBER 1938

Fig. 10

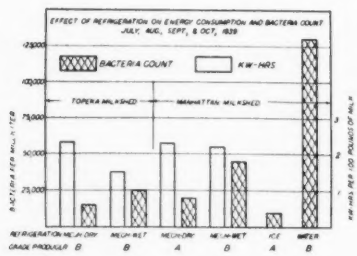

Fig. 11 (left)

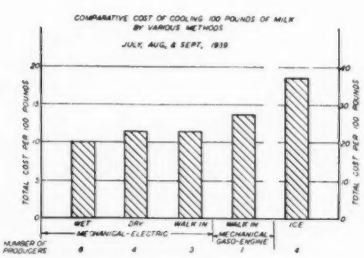

Fig. 12 (right)

field study. The electric aerator shown in Fig. 1 consisted essentially of an electric motor driving a stirring propeller fastened to the same shaft as the air fan. Temperatures were secured by means of a thermocouple near the center of the can.

A total of 38 watt-hour meters were installed to measure the energy requirement of the cooling equipment. The time of operation of the compressors was determined by recording ammeters, servis recorders, and self-starting electric clocks. Weights of milk production were obtained from the individual dairymen and from the pasteurizing plants to which the milk was sold. Bacteria counts were obtained from the milk inspectors at the pasteurizing plants and the city dairy inspectors or milk sanitarians. Temperatures were taken by recording thermometers and mean air temperatures were obtained from the U. S. Weather Bureau offices at Topeka and Manhattan.

Fig. 4 shows the rate of cooling milk when stored in 10-gal cans in a dry storage box. Fig. 1 shows the locations where the temperatures T_1, T_2, and T_3 were taken. The solid and broken lines near the bottom of Fig. 4 show the air temperatures in the refrigerator. The rate of cooling when an electric fan was delivering a cold air blast against the can is shown by the broken line and is much more rapid than in still air. These curves indicate that milk cannot be cooled satisfactorily by means of cold air.

Fig. 5 shows the rate of cooling with well water. The effect of stirring the milk three times during the first hour

was to lower the average temperature about 5 F. Continuous agitation increased the rate of cooling considerably T_1 was the temperature near the top of the milk while T_3 was the temperature 3 in from the bottom of the can. The temperature of the cooling water is shown by the bottom solid line. These data show that well water having a temperature of 60 F can be used for the cooling of grade B milk.

Fig. 6 shows the effect of water agitation on the rate of cooling milk when stored in 10-gal cans. The solid lines show the rate of temperature change when the cooling water was not agitated, and the broken lines show the rate of cooling when the water was agitated. These data show that the water must be agitated to meet the cooling requirements for grade A milk and that the water need not be agitated to meet grade B cooling requirements.

Fig. 7 shows the effect of stirring the milk stored in 10-gal cans when the cooling water was not agitated. Comparing this curve with Fig. 6, it was shown that the milk cools at about the same rate if the milk was stirred and the water was not agitated or the water was agitated and the milk was not stirred.

When the water was continuously agitated and the milk was stirred at the same time milk could be cooled from 98 to 50 F in 16 min or less, in various tests. Results of one of these tests are shown in Fig. 8. Fig. 1 shows the location of the thermocouples at which the temperatures T_A, T_1, T_2, T_3, and T_4 were taken. T_A was the air temperature one inch above the milk. Results obtained in the laboratory verified field data.

Fig. 9 shows the effect of an ice bank on the rate of cooling milk stored in 10-gal cans in a wet storage cooler. When cooling with an ice bank on the coils the temperature of the cooling water was nearly constant, while with no ice bank the temperature of the cooling water was raised and the milk was not cooled as rapidly as with the ice bank. The temperature rise of the cooling water is dependent upon the relation of the quantities and initial temperatures of milk and water and ice. It is not important that a cooler have an ice bank; however, it must have enough reserve refrigeration to cool a given quantity of milk. One pound of ice, for example, having a temperature of 32 F, when melted and raised 6 F absorbs 150 Btu. It requires 25 lb of water, when raised 6 F to absorb a similar amount of heat. Many manufacturers use an ice bank on their coolers, thereby decreasing size and original cost. For best operation there should be just enough stored refrigeration to cool the load and sufficient refrigeration built up for the next load by the time it is placed in the cooler.

VALUE OF INSULATION

There were several homemade boxes in the Manhattan and Topeka milksheds and there was considerable speculation among the dairymen as to the costs of an insulated box and a noninsulated box.

Fig. 10 shows the effect of temperature and insulation upon the energy consumption of two dry storage boxes. The top curve shows maximum outside temperature for the month of September, 1939, an exceptionally warm month. The lower and middle curves show the energy consumption per 100 lb of milk cooled, for a galvanized iron box with three layers of Celotex insulation and a 4-in concrete box with no insulation.

Fig. 11 shows the effect of the method of refrigeration on the energy consumption and bacteria count for 28 producers in the Topeka and Manhattan milksheds. It was interesting to note that when cooling with ice, milk with a low bacteria count was produced. These dairymen use the recommended practices for all three phases of milk production. It was also noted that all bacteria counts were well below those specified by the standard milk ordinance.

Most of the producers using mechanical refrigeration were using equipment having a capacity much larger than needed for their present production. Tests showed that as the load increases in per cent of rated capacity, the cooling costs per unit of milk are lowered. The range was from around 3 kw-hr per 100 lb of milk cooled at 20 per cent of rated capacity, to less than 1.5 kw-hr at full rated capacity. The lowest costs should occur at rated capacity of the machine. Many of the producers purchased large equipment with the idea of increasing their herds.

Table 1 shows the method of calculating the cost of cooling milk by the wet storage method, dry storage method, and by ice.

TABLE 1. COMPARATIVE COST OF COOLING MILK
July-August-September 1939

	Wet-storage	Dry-storage	Ice
Original cost	$275	$355	$200
Fixed costs			
Depreciation at 10 per cent	2.29	2.96	1.66
Interest at 3 per cent	.69	.89	.50
Repairs at 3 per cent	.69	.89	.50
Operating costs			
Energy at 3c per kw-hr	3.39	4.11	
Ice 30c per cwt.	——	——	27.00
Labor 30c per hr.	——	——	2.25
Hauling	——	——	3.00
Fuel	——	——	.75
Oil	——	——	.30
Total cost per month	$7.06	$8.85	$35.96
Amount cooled per month	7847 lb	6941 lb	8850 lb

Fig. 12 shows the comparative costs of cooling 100 lb of milk by the various methods. The cost of cooling with ice is exceptionally high and is the average of four grade A producers. This cost no doubt could have been lowered 20 to 30 per cent by proper utilization of the cooling effect of the ice.

Records were kept of electric energy consumption for 20 dairies during July, August, and September 1939. Tabulations of the figures for August showed a range from 230 to 1264 kw-hr total power use per farm, with an average of 595 kw-hr. The range in power used for cooling milk was from 89 to 492 kw-hr, with an average of 210 kw-hr. On one farm the current used for cooling milk was less than 19 per cent of its total consumption, and on another it was 60 per cent. The average was 35.3 per cent.

From the investigations thus far completed, the following conclusions are drawn:

1 In a survey of 1,144 dairy farms in Kansas, there are 25 per cent grade A, 74 per cent grade B, and 1 per cent grades C and D. Only 20 per cent of this number used mechanical milkers, 24 per cent did not cool their milk, 40 per cent used well water, 12 per cent used ice, and 24 per cent used mechanical coolers.

2 Cold air is practically worthless to cool milk stored in 10-gal cans.

3 If water is available having a temperature of 60 F or below, it can be satisfactorily used as a cooling method when producing grade B milk.

4 When well water is used to cool milk stored in 10-gal cans, the rate of cooling can be doubled by stirring the milk three times the first hour. *(Continued on page 471)*

Cultural Control of Bindweed

By C. W. Smith
MEMBER A.S.A.E.

IN 1934 the department of agricultural engineering at the University of Nebraska, in cooperation with the International Harvester Company local branch house and a farmer, Albert Retzlaff, undertook to eradicate bindweed on a 32-acre tract. It was agreed to do this work by a summer fallow clean-tillage method. It was agreed by all parties concerned that cultivation was to begin as soon as possible each time after the weed began to emerge from the soil. This work was begun on June 13, and was continued through the remainder of that year, all of 1935 and all of 1936, making a good two and one-half seasons of work on that field. Even then, at the close of 1936, one could occasionally find a surviving bindweed plant. Those that could be found were chlorated in the fall of 1936 and the field checked to corn the following year and watched closely. Corn does not follow well on such summer fallowed ground, having a period in middle summer when the leaves turn purple and it grows very slowly. However, this particular field came out fairly well and due to the drought, was practically the only field in that vicinity which produced corn, about 25 bu per acre.

There has been ample information gathered since this work was started in 1934 to show that one does not need to commence cultivations immediately after the emergence of the bindweed plant. The plant can grow for several days after it has emerged and still be set back as badly by a cultivation as if cultivated sooner. Thus one can reduce the number of cultivations required. We were interested, however, in following through to its ultimate end the plan which had been agreed upon, and it was interesting to note that this field had been cultivated over seventy times when it was turned over to the farmer as a clean field. We wish to emphasize this fact, the entire field was scrutinized very carefully and we feel that many others would have pronounced the job a 100 per cent kill sometime before the last few surviving bindweed plants gave up.

The agricultural engineering department was then anxious to see if there was some other way of handling the bindweed control problem and decided to try the following plan: To prepare a seedbed carefully for checked corn; cultivate the corn in both directions as long as possible with a two-row power cultivator and when the corn was too big to be handled with a tractor and power cultivator, to use a single-horse, one-row cultivator and continue the cultivation through the season as long as necessary to keep down the bindweed. It was also planned to follow each second cultivation with a hoe and take out those plants which were so near the corn stalks that they could not be cut out with a cultivator.

In describing the work which we have done on this basis, we want to make it perfectly plain that this is no procedure which is being recommended; it was merely a trial to see if there was any other way in which this bindweed eradication work could be done which might meet with the approval of some farmers.

The hand work on such a project was the big drawback. Some of the things to be gained were: First, use of the land instead of throwing it out of cultivation for two or more years. Second, we felt the land might be better protected against both wind and water erosion with a crop on it than it would be exposed. Third, a crop growing on the soil might prevent some of the injurious effects which constant tillage has on soil as evidenced by the fact that corn would not follow such work very satisfactorily. Fourth, our country seems to be harrassed at the present time with more labor than we have a market for, and it was thought that such a scheme might have an appeal for the use of some extra labor. These were among the primary reasons for attempting some bindweed control work along these lines.

The first field chosen for this work was one of 17.44 acres badly infested with bindweed. A few figures from the summary of this work may be of interest. Thirty cents an hour was paid for this work with a hoe and the cost of hoeing on this 17 acres was $85.80 for the year 1937. The total cost per acre of all work done for the season 1937 was $15.92. It was estimated that the cost of plowing, harrowing, planting, and four cultivations as would be conservatively estimated for the production of corn without any weed control project, would be $3.76 per acre. This subtracted from the $15.92 would leave $12.16 per acre as the cost which could be attributed to the weed control project for the first year. This work was continued through the season 1938 and the cost of the hoeing for that year amounted to $36.68. The weeds were very much easier to control the second season and the total cost per acre of work done on this field was $8.47. Plowing, harrowing, planting, and four cultivations this season cost us a little more than it did the first season—$4.39. This subtracted from the total cost of $8.47 left $4.08 to be charged to the cost of bindweed work for the season 1938.

There were still a few plants surviving in 1939, and it was decided to handle the field in the same way for that season—to check to corn and control the bindweed by cultivating and hoeing. The total cost of the hoeing required for 1939 for the field of 17.44 acres was $25.20. Only three cultivations with the tractor cultivator were required; consequently, plowing, harrowing, planting, and three cultivations cost $3.56. This subtracted from $5.32 leaves $1.76 per acre as the cost of the bindweed project for the 1939 season. The field was watched carefully at the close of the season and about nine surviving plants were found. These were chlorated and the field turned back to the farmer as a clean field for his use in 1940.

In 1938 we started a second field of 15.78 acres and managed it in practically the same way as we had the 17-acre field. Work on that field is being continued this season, but to date the results appear to confirm quite well the work on the first field.

In conclusion we wish to say that this is not a procedure which we are recommending, but merely the results of some work which may throw light on methods of control and have value in the program of some people. The corn produced compared favorably with any in the immediate vicinity. The control work can be fully as effective as that of clean tillage.

A contribution of the A.S.A.E. Committee on Weed Control (1939-40). Author: Professor of agricultural engineering, University of Nebraska.

The Electric Ultramicrometer Circuit as a Drawbar Dynamometer

By G. W. Giles
MEMBER A.S.A.E.

THIS dynamometer employs a radio circuit commonly called the "electric ultramicrometer circuit". This circuit is not new. It was first described by Whiddington[1] in 1920. Other scientists have improved and used these circuits for various purposes[2,3,4].

There are a number of circuits used for electric ultramicrometers. Probably the simplest and most self-contained is the Hartley circuit. It may not be as stable as other types, but a drawbar dynamometer needs to be portable.

The Circuit. A wiring diagram of the Hartley circuit is shown in Fig. 1. C is an electrostatic condenser consisting of two plates. Each plate is approximately 4¾ in square. The distance between the plates is variable. Coil XY consists of about 150 turns of 28-gage enameled copper wire wound close together on a bakelite cylinder 3½ in in diameter. Coil YZ is a similar coil wound on a bakelite cylinder 3⅛ in in diameter. The two coils are connected in series and set coaxially. The small coil is adjustable inside the large coil. M is a d-c milliammeter with a range of 0-1 milliamperes.

Operation of the Circuit. Briefly, the circuit functions as follows: Current flows in the circuit through the vacuum tube, B battery, meter M, and the coil ZY. This current is called the plate current. High-frequency oscillations are set up in the circuit XYZC. The frequency is given by the equation

$$F = \frac{1}{2\,\Pi\,\sqrt{LC}} \qquad [1]$$

where L = inductance of coils (henries)
C = capacity of the condenser (farads).

These oscillations affect the polarity of the grid, which in turn affects the amount of the plate current. The greater the frequency of the oscillations, the greater the plate current. The frequency of the oscillations, other factors remaining constant, will be increased by reducing the capacity of the condenser C (Formula 1). The capacity of the electrostatic condenser may be decreased by increasing the distance between the plates. The following equation shows this relation:

$$C = \frac{KA}{4\,\Pi\,D} \qquad [2]$$

where C = capacity of condenser
A = area of one plate
D = distance between plates
K = constant depending upon the dielectric.

The two condenser plates are mounted in the line of draft in such a way that pull will increase the distance between them, thus increasing the plate current.

The resistances R_1 and R_2 and the C battery are shunted across the meter. With no load on the drawbar unit and the condenser plates in normal position, the resistances R_1 and R_2 are adjusted so that the drop of potential across the meter due to the plate current is equal to the drop of potential due to the C battery. When this is true, the meter will read zero. Any increase in the plate current will then cause the meter to deflect. This shunt, commonly called the "zero shunt", is of great value in adjusting the meter to read zero previous to measuring the drawbar pull. Two resistances are used so that adjustments are made more quickly and more accurately.

The Drawbar Condenser Unit. Fig. 2 shows a picture of the drawbar unit along with the instrument box. The unit weighs 15 lb and consists of two heavy flat springs attached at the ends to form two simple restrained beams. The pull exerted by the drawbar is applied to the center of the beam. The two springs carry the two condenser plates. These plates are made of steel and insulated from the springs. The plates are shellacked to prevent electrical contact. They are adjusted to give the desired maximum load. The closer the plates, the greater the deflection of the meter for a given load. If the plates are too close, the circuit will not oscillate. Also, if the plates are drawn too far apart (approximately ¼ in), as under load, the circuit will not oscillate.

This drawbar unit was satisfactory for 0-2900 lb of pull. The condenser plates were adjusted by a cut-and-try

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[1]Bazzoni, C. B., Ultramicrometer circuits, Journal of the Franklin Institute, Vol. 202, July 1926, pp. 35-50.

[2]Mershon, A. V., Recent application of the electric micrometer, General Electric Review, Oct. 1928, p. 526.

[3]Olken, H., Ultramicrometers that measure by radio, Instruments, Vol. 5, Feb. 1932.

[4]Dowling, J. J., The recording ultramicrometer; its principles and application, Philosophical Magazine and Journal of Science. Vol. 46, S. 6, July 1923, pp. 81-100.

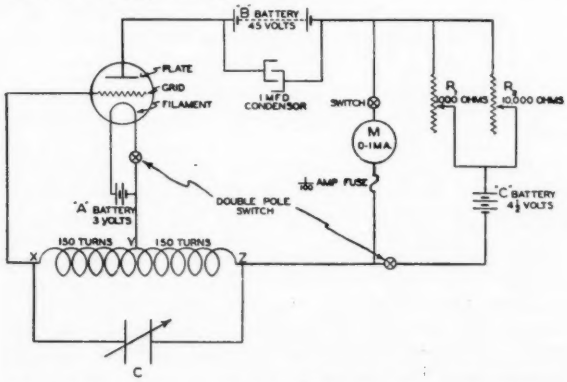


FIG. 1 WIRING DIAGRAM OF A HARTLEY ELECTRIC ULTRAMICROMETER CIRCUIT

process at zero pull to get the desired maximum load. With the plates as close as possible, the unit gave a full-scale deflection (1 ma) with a 1200-lb pull. This unit is the first one that was designed. Room was permitted for adjusting the condenser plates to determine the effect on the circuit. The overall length of the unit including the hitches is 7⅞ in. A shorter coupled and more compact unit could be designed.

For accurate work the condenser plates should be enclosed. Dust in the air will change the dielectric, thus affecting the capacity (Formula 2).

The Instrument Box. Fig. 2 shows the instrument box. It weighs 22 lb, including the batteries. Fig. 3 shows the box with all sides removed except the front panel. All parts are mounted on the front panel. The circuit is wired with 16-gage enameled copper wire and insulated with spaghetti.

The coil YZ is built so that it may be adjusted inside the coil XY. The distance between the coils should be no less than about ⅛ in. If the coils are too close the wires act as condensers and the circuit will not oscillate. As the coil YZ is moved into the coil XY (increase coupling), the sensitivity is increased. Maximum coupling was used. The amount of coupling also seems to affect the shape of the calibration curve. After the amount of coupling is determined, the coils should be permanently attached to each other.

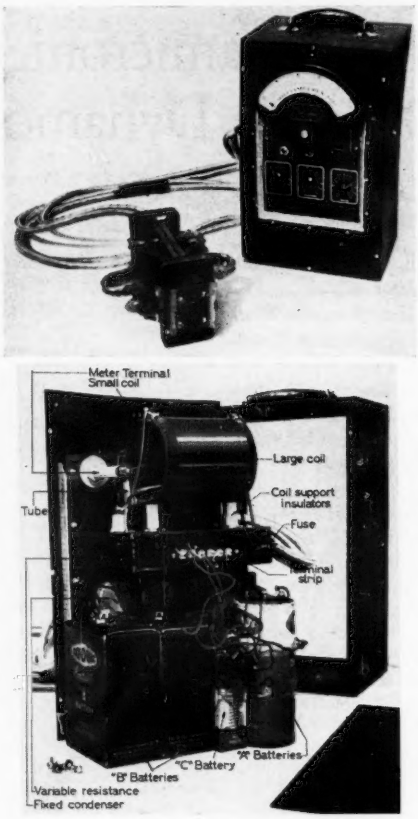


FIG. 2 (TOP) COMPLETE DYNAMOMETER. FIG. 3 (BOTTOM) INSTRUMENT BOX, WITH ALL PARTS EXCEPT BATTERIES MOUNTED ON THE FRONT PANEL OF THE INSTRUMENT BOARD

The meter has a scale length of 5.8 in. A longer scale would permit greater accuracy in reading. It is provided with special blunt pivots to resist shock and is overdamped to prevent too rapid movements of the hand.

Transmission Wires. The two wires leading from the drawbar condenser unit to the instrument box are crystal microphone wire of any desired length. Each single wire is shielded, but it is best not to ground this shield. It is too close to the wire and will function as a condenser. Each wire is contained within ⅜-in shielding cable. The shielding of this cable is grounded to the drawbar unit and to the instrument box. Unless these wires are shielded they act as condensers, the capacity of which is large compared to the two plates in the drawbar unit. The effect of the displacement of the two plates will be small and the dynamometer will not be sensitive. The shielding also prevents the capacity of external bodies affecting the reading of the meter.

Sensitivity. Sensitivity may be defined as the meter deflection for a given drawbar pull. Increasing the sensitivity is desirable (1) for the maximum pull on the drawbar or (2) for the lighter pulls, after the sensitivity for the maximum pull is established.

The following methods may be used for increasing sensitivity:

1 Increase the size of the condenser plates. The capacity of the condenser plates varies directly as the area of one plate. For a given displacement of the plates, there will be a greater change in capacity for the larger plates than for the smaller ones. The disadvantage of this method is the increase in size of the drawbar unit.

2 Vary the spacing of the condenser plates. The closer the plates, the greater the sensitivity. This may also be used for regulating the maximum pull desired for a drawbar unit.

3 Use lighter springs in the drawbar unit. The displacement of the condenser plates will be greater for a given pull if lighter springs are used. Two units may be built: one with light springs for the light pulls (0 - 1000 lb) and one with heavy springs for the large pulls (0 - 3000 lb).

4 Build the drawbar unit for the lighter pulls and for the heavier pulls, switch into the circuit a fixed condenser in parallel with the condenser plates on the drawbar unit. This means that a greater displacement of the condenser plates is necessary for the heavier loads.

5 Use a double-scale meter. The meter must have an internal shunt to be used for the heavier pulls. This method will also require a large displacement of the condenser plates.

6 Increase the plate voltage. I selected this last method for increasing the sensitivity for the light pulls. The dynamometer was designed and adjusted for 0 - 3000 lb load when using 45 volts of B battery. For lighter loads the two B batteries were placed in series to secure 90 volts. This voltage was cut down by a variable resistance of 0 - 3000 ohms (not shown in Fig. 1) to give any desired sensitivity. With 90 volts the maximum pull was 1200 lb for a full-scale deflection of the meter. Difficulty was experienced with a serious drifting of the meter hand. For this reason the method is not satisfactory. This trouble may be remedied by placing a resistance and condenser in series with the grid circuit. This, however, cuts down on the sensitivity and little is gained.

The most satisfactory method is No. 3. Two or more interchangeable drawbar units may be used for a range of pulls.

Performance. In measuring the draft of some implements rather wide and rapid fluctuations of the meter hand occurred. However, the high and low values could be read. If high and low values are recorded as rapidly as possible during a test and these values are averaged, a fairly accurate average draft value is secured. The meter used in this dynamometer was medium damped. A meter may be purchased with as much as four times the damping of the meter that was used. It is suggested that the heavier damped meter be purchased.

A motion picture may be taken of the meter face for

the purpose of getting average draft values and keeping records. Since the current range (0 - 1 ma) is small, a recording meter can not be used.

Calibration curves run on this dynamometer over a period of several weeks gave a change of as much as ± 60 lb at 2900 lb of pull. Part of the error may be due to the different adjustments of the "zero shunt" necessary because of changes in the circuit. Also there may be an error due to change in temperature.

There may sometimes be a slight drift of the meter hand due to the impossibility of the portable batteries supplying a steady constant current. If portable batteries are used they need to be replaced frequently. The largest drain is from the B battery. If the voltage of the B battery drops, the sensitivity is decreased. It would be wise to place in the circuit a voltage regulator and voltmeter for adjusting and maintaining a constant voltage on the plate.

Advantages. The dynamometer has the following advantages:

1 Has a zero adjuster. One may always make the meter read zero.

2 Drawbar unit will permit exceedingly close coupling.

3 Drawbar unit is rugged if condenser plates are protected.

4 Drawbar unit may be used for compression forces as well as tension forces.

5 Instrument box may be located as far from the drawbar unit as desired.

6 Reasonable in cost and simple to make. The approximate cost of the parts, excluding the drawbar unit, is forty dollars ($40.00)[5].

7 If portable batteries are used, the instrument is self-contained.

Disadvantages. Limitations to the usefulness of the device are as follows:

1 The meter is delicate.

2 Batteries and tube must be kept in good condition.

3 Time must be given for the circuit to warm up.

4 If condenser plates become bent, the calibration will not be true.

5 There is no convenient method for controlling the damping of the meter hand in the field.

6 An inexpensive, simple method of recording drawbar pull is not available.

7 This dynamometer is not as dependable as some of the other types.

Possibilities for Other Uses. In some machines, such as the combine, it is desirable to measure the drawbar pull and also the torque of the power take-off shaft. This dynamometer may easily be adapted as a torque dynamometer. There are three possibilities for designing a torque dynamometer, namely, (1) hydraulic, (2) recording device mounted on the rotating shaft, and (3) electrical. Of the three methods the electrical instrument has the best possibilities. Electrical energy may easily be taken from a rotating shaft. For the combine mentioned only one instrument box need be used. By simply throwing a switch one may change the meter from the drawbar to the power takeoff, or vice versa. This can not be done with either of the first two methods. A torque dynamometer to measure the power supplied by the belt pulley or drivewheel of a tractor may also be designed along this line.

By using one instrument box and several condenser units, forces (compression or tension) could be measured at various places on a tillage machine. It would be necessary, of course, to switch from one condenser unit to another. All values could not be read at exactly the same instant.

Scientists have made measurements to one-millionth of an inch with ultramicrometer circuits. With such accurate measurements the two condenser plates may be mounted on the spoke of a rotating wheel and the tension and compression forces measured.

This ultramicrometer circuit may have some possibilities for the determination of soil moisture in plot work. Similar devices have been used for measuring the moisture content of grain. Two sharp-pointed insulated rods may be used as a condenser. The capacity of this condenser will vary depending upon the dielectric. Moisture in the soil will affect the dielectric. The instrument would need to be calibrated for a certain soil. If a change occurs in the chemical and certain physical properties of the soil the calibration would not be true. However, a check could be made frequently to correct for the chemical and physical changes.

[5]A list of materials and approximate prices will be furnished by the author on request.

Results of Investigations of Milk Cooling

(Continued from page 467)

5 The average amount of ice used to cool 100 lb of milk during the months of July and August, 1939, for four grade A producers was 107 lb, while for four grade B producers an average of 41 lb was used per 100 lb of milk.

6 When using the wet storage method of cooling, the rate of cooling can be increased six times by agitating the cooling water.

7 When using the wet storage cooling method, the rate of cooling can be increased six times by stirring the milk continuously during the first hour.

8 When using a 4-in concrete storage tank, the energy consumption to cool milk can be reduced 50 per cent by proper insulation.

9 The cost of cooling milk when using a wet storage method can be reduced 25 to 40 per cent by operating the coolers at their rated capacity.

10 Milk of a very low bacteria count can be produced when cooling with ice provided proper methods are employed.

11 The cost of cooling milk is cheapest when using the wet storage method and most expensive when using ice.

12 Energy required in cooling milk can be reduced from 18 to 32 per cent by running water at 60 F through the top half of the tubular surface cooler.

13 Energy required to keep the wet storage box cool varied from 20 to 28 per cent of the total energy required at rated capacity of the cooler.

14 Mechanical refrigeration, when operated by an electric motor, was the most satisfactory method of those studied for cooling milk.

The Drying of Grasses

By R. M. Ramp
JUNIOR MEMBER A.S.A.E.

GRASS drying has been practiced for some time in England, but it is a relatively new development in this country. The Foxden Farms in Delaware have done considerable work on drying grasses.

Grasses in an immature stage have long been known to have a high protein, low fiber, and high carotene content. These features of dried grasses make it of special value as a dairy feed. Grass drying should not be confused with the artificial drying of hay. Grass drying produces from young pasturage a feed that approaches the concentrates in protein content, digestibility, and in the small proportion of indigestible fiber. With hay drying, the original material is in a more advanced stage of growth and the end product is not a concentrate but is good hay.

The regular haymaking procedures are impractical in curing short grasses because of the difficulty in handling and loss of nutrients during the process of sun curing. In the hay method, approximately 80 per cent of the carotene is lost during the first 24 hr of exposure, while it has been found that the carotene content of machine-dried grasses was only slightly less than that of the freshly cut grasses. In order to secure the highest nutrient content, the grass should be cut whenever it reaches the height of 6 to 10 in. A special harvester (see accompanying view) is equipped with a lespedeza cutter bar and a special type of shoe. The machine deposits the cut material in two-wheeled carts that are detached when filled. While one cart is hauled in from the field, another cart is filled, thus making it possible to keep a continual supply of grass at the drier.

This drier was modeled after the Billingham type and is a two-tray batch drier with heat supplied by an oil burner. Hot gases are drawn through the drier by means of a fan driven by a 15-hp motor. The gases first pass through a tray of partly dried grass and then through another tray of fresh grass. The inlet temperature of the hot gases is thermostatically controlled at 250 to 300 F, and practically all of the heat is utilized in evaporating moisture.

The grass that is brought in from the field is forked into one tray, which is conveyed upon rollers into the drier. When the grass is half dried, the tray is withdrawn and its contents forked into the second tray. The first tray is refilled with wet grass, and then both trays are rolled into the drier. As soon as the moisture content of the grass in the partly dried tray has been brought below 10 per cent, the drying cycle has been completed. Each stage of drying takes 15 to 30 min, depending upon the amount of water to be evaporated and upon the kind of grass.

After the dried grass has cooled, it is tightly baled in a power baler. Baling is used because it is thought that the rate of loss of carotene in storage is lower when the grass is tightly baled.

Approximately one ton of dried material is produced in 8 hr from grasses with a normal original moisture content of approximately 80 per cent. The total cost of producing a ton of dried material under the conditions of this experiment has been found to average $28. This is reasonable, considering that a concentrate, such as alfalfa leaf meal of equal food value would cost approximately $45 per ton.

Presented before the Power and Machinery Division at the annual meeting of the A.S.A.E. at State College, Pa., June 17, 1940. Author: Instructor in agricultural mechanics, University of Delaware.

A VIEW OF THE REDPATH HARVESTER USED FOR CUTTING GRASSES IN THE IMMATURE STAGE ON THE FOXDEN FARMS IN DELAWARE

CONCLUSIONS

1 Artificial drying of immature pasture herbage in a two-tray, batch drier, followed by baling, gives a product which retains most of its original green color.

2 More dry matter can be obtained per acre per year by frequent clipping and drying, than by harvesting grass as sun-cured hay.

3 Frequent clipping of the immature grasses increases the acreage yields of protein 40 to 50 per cent over that recovered by the usual haymaking procedure.

4 More than five times as much carotene was preserved through artificial dehydration as by field curing.

5 Reduction of moisture in the grasses below 10 per cent by artificial drying is valueless.

6 Loss of carotene during storage in bales is most rapid during the first few months, particularly in hot weather. The loss averaged 50 per cent during the ten months experimental period. The final product still contained two to five times as much carotene as was found in hay at time of storage.

7 The results obtained from the artificial drying of grass are very favorable, but the equipment cost at the present time makes it prohibitive as a universal practice in Delaware. However, we can reasonably look forward to enough improvement in the grass-drying equipment and methods to overcome the present high cost of drying grasses.

Progress in Fire Protection

THE use of CO_2 in smothering hay and grain fires in storages has been considered. It was hoped that some tests under controlled conditions could be taken up, but as funds for such work have been curtailed in the U. S. Department of Agriculture and no interested state has been found, such work has not been instituted. It is hoped that some instances will develop under actual farm conditions where the offer of the manufacturer to supply a drum of gas, hose for connecting the pipe, and a control valve, will be used. Some cases are on record where soda fountain equipment has been used with good effect. However, the pipes and valves were too small for a rapid discharge and frosting developed which obstructed the flow. The company recommends a 2-in pipe as a minimum.

Some of the manufacturers of fireproofing and fire-resisting farm building materials have developed, or are in the process of producing, plans of structures that will at least retard the spread of fires by confining them to the building in which they start or prevent their spread by having a nonflammable exposure on the outside surfaces.—*From a report of the A.S.A.E. Committee on Farm Fire Prevention and Protection for 1939-40, J. R. Haswell, Chairman.*

Research Work in Wheat Storage

By C. F. Kelly
JUNIOR MEMBER A.S.A.E.

STORAGE of wheat on the farm has in the past few years received much attention from both farmers and government agencies. Many questions and problems have arisen as to the best types of storage structures for the farm, the relative suitability of the various materials of construction, the grades and moisture content of wheat that can be safely stored for long periods, effectiveness of underground storages, the use of absorbents for drying wheat in storage, the suitability of various bin designs for fumigation, the possibilities of developing a portable wheat drying machine that can economically remove enough moisture from damp wheat to make storage safe, and bin ventilating systems for damp wheat. In order to find an answer to these questions, a research program, supported by Bankhead-Jones funds, was instituted in 1936 by the Department of Agriculture, represented by the Bureaus of Agricultural Engineering, Plant Industry, and Agricultural Economics, and the agricultural experiment stations of North Dakota, Kansas, Illinois, Maryland, Ohio, Michigan, and Minnesota. In 1936 and 1937 the state mill and elevator of North Dakota also cooperated by lending large quantities of wheat for use in the experiments in that state. Field stations and experimental bins were set up at Fargo, North Dakota; Hays, Kansas; Urbana, Illinois; and College Park, Maryland, each in cooperation with the respective agricultural experimental station. Thus, all the wheat-growing regions except the West Coast were included in the investigations. The experimental bins ranged in size from 20-bu to 1000-bu capacity, about ten of the small and eight to twelve of the larger bins being erected at each station. These bins varied in materials of construction, amount of insulation, size, and type of ventilating systems, if any.

BIN TEST METHODS AND EQUIPMENT

The different bins and ventilating systems were compared by noting the temperature changes of the grain in different parts of the bin, the rates at which moisture was removed from the stored wheat, the commercial grade of the wheat when placed into storage and during the storage period, and the changes in the condition of the wheat as indicated by its fat acidity[1] and per cent germination. Temperatures of the stored wheat were obtained by thermocouples placed in representative locations and read by means of a potentiometer. Average samples were taken from the bins with standard grain triers and analyzed by the official grain inspectors of the Agricultural Marketing Service to determine moisture content, grade, fat acidity, and milling and baking qualities. Germination percentages were determined by the Bureau of Plant Industry. In order to learn the condition of the wheat in different parts of the bins, additional samples were taken from selected locations and tested for moisture content, fat acidity, and germination.

Those bins at each station used for determining the relative merits of the different materials of construction—wood, metal, and concrete—were all filled from the same lots of wheat through a large divider, so that the wheat in all bins would be as nearly identical as possible. For determining the maximum moisture content and temperature for safe storage over various lengths of time, identical bins were filled with wheat of moisture contents slightly above, equal to, and slightly below that specified by the official grain standards for the straight numerical grades of the various classes of wheat. Field studies of ventilation were made at all of the stations, in bins of several capacities, up to 1000 bu. These were filled with moderately damp wheat, then closely observed for as long as necessary to determine the value of the equipment and methods used.

PORTABLE DRIER DEVELOPMENT

Storing of damp wheat in ventilated bins may not always prove dependable and economical; hence, in 1937 the development of low-cost portable driers employing heat was started. Two methods, differing in the manner of using heat and air, are being tested. Good results are being obtained at the University of Maryland with a drier in which the grain is heated by being passed through an extended surface-heating coil, while a stream of cool air flows over it in the opposite direction to remove the moisture. The moisture content of 17 per cent wheat can be lowered to 13 per cent by this machine at a rate of 50 bu per hr. By reducing the rate of feed, the amount of moisture removed can be further increased. Coal is used for fuel and water as the heat carrier. Another type of machine, being developed at the Arlington experimental farms, Rosslyn, Virginia, heats the grain by direct contact with the inside of a drum revolving in a heated oven. The wet wheat, heated to a temperature of about 140 F (degrees Fahrenheit), passes by gravity down between two screens spaced about 6 in apart, where it receives a blast of cool air. The wheat is in the air flow for a period of 8 to 10 min, in which time it is both cooled to air temperature and dried. The experimental model built in 1939, mounted on a truck, will dry 16 per cent wheat to 14 per cent at the rate of 100 bu per hr. Oil is used for fuel[2].

To check experimental data obtained at the field stations, several surveys of storage conditions on farms have been made. The storage of wheat under seal by the AAA has provided additional opportunity for us to observe wheat of which the initial condition was known.

Laboratory tests have been conducted along several lines. The Bureau of Plant Industry, in its Washington laboratories, has experiments under way to determine the part played by fungi in the spoilage of wheat and the effectiveness of certain fungicides in inhibiting such spoilage. The spoilage known in the trade as "sick wheat" is also being studied.

As stated before, samples are taken from the wheat under observation for moisture, grade, milling and baking, germination, and fat acidity tests. These samples are, of course, used to determine in the laboratory the extent of deterioration. In this connection it was found that the

Presented before the Farm Structures Division at the fall meeting of the American Society of Agricultural Engineers, at Chicago, Ill., December 5, 1939. Author: Associate agricultural engineer, Bureau of Agricultural Chemistry and Engineering, U. S. Department of Agriculture.

[1]The fat acidity determination is a chemical test based upon the amount of free fatty acids in the wheat. Fat acidity is determined by the number of milligrams of potassium hydroxide required to neutralize the free fatty acids in 100 grams of wheat.

[2]For more detailed information on this drier, see "Methods for drying grain on the farm," by C. F. Kelly, Agr. Engr. 20:4 (April 1939).

external evidences of wheat deterioration usually are not apparent until the condition of the grain has been lowered enough to affect its commercial grade. However, per cent germination and fat acidity of sound wheat were found to be valuable indices of incipient deterioration that is not apparent from grade examination. Changes in both germination and fat acidity are found to be accelerated under high moisture and temperature conditions, and these changes are measurable before the development of abnormal odors or kernel damage. With wheat of low moisture content and low temperature conditions there is little loss in germination or increase in fat acidity.

Laboratory experiments were also conducted in Washington and in the field stations to determine basic data for the design of ventilating systems. These included tests and calculations to determine air pressures available from the wind, rates of air flow through wheat under low static pressure, effect of chaff, bin wall surface area and wheat density on rate of air flow, and rates of moisture removal from stored wheat under various conditions of air flow and grain depth.

Recently an experiment was set up to determine the effect, if any, of storage in creosote-treated bins on the odor, official grade, germination, and milling and baking qualities of the stored wheat.

Several problems which are of immediate interest at this time in connection with farm storage structures are (1) strength requirements, (2) weather tightness, (3) insect control, and (4) bin ventilation.

STRENGTH REQUIREMENTS

No recent investigations have been made of the various pressures produced in a structure by stored wheat. However, several mathematical treatments, as well as a description of numerous experiments to determine the law of grain pressures are given in detail by Ketchum[3]. The calculated solutions, obtained by means of either Janssen's or Airy's formulas, agree closely with experimental data. Long[4] has summarized the existing knowledge of structural design of grain bins and cited several types of failures and their causes.

Because all formulas make use of one or more constants, the values of which vary with the kind and condition of grain to be stored and the material of bin construction, much judgment in selecting the proper values must be used in design work of this type, and on large structures an experienced engineer should be consulted. It should be remembered that, even in small bins, the pressures are quite large. For instance, in a 1000-bu rectangular bin, 12x14 ft and 8 ft high, filled with wheat weighing 50 lb per cu ft, the lateral pressure at the bottom of the side wall will be about 180 lb per sq ft, the load carried by the side walls 340 lb per lineal foot, and the pressure on the bin bottom about 290 lb per sq ft. A round metal bin, 14 ft in diameter and 8 ft high, capacity about 1000 bu, and filled with the same kind of grain, will have a lateral pressure at the bottom of about 190 lb per sq ft, a load carried by the side walls of about 300 lb per lineal foot, and a pressure on the bin bottom of about 310 lb per sq ft. In a larger metal bin of 2036-bu capacity, 18 ft in diameter by 10 ft high, the lateral pressure at the bottom will be about 240 lb per sq ft, the load on the bin walls per lineal foot about 470 lb, and the vertical pressure approximately 400 lb per square foot. In making these calculations Janssen's formula was used as follows:

$$L = \frac{wR}{u'}\left(1 - e^{\frac{-ku'h}{R}}\right)$$

in which L = lateral pressure of wheat in pounds per square foot
w = weight of grain in pounds per cubic foot
R = hydraulic radius of bin
u' = coefficient of friction of wheat on bin wall
k = ratio of lateral to vertical pressures
h = depth of grain in feet

A value of 0.6 was used for k, 0.441 for the coefficient of friction of wheat on wood, and 0.365 for coefficient of friction of wheat on metal. The pressures as calculated above are approximately the same as would be obtained with Airy's formula using an angle of repose for wheat of 18 deg.

Ordinarily the wall material of 1000 to 2000-bu round metal bins is strong enough to take the "hoop" tension. However, structural failures may occur in the vertical seams between wall sheets or at the junction of the wall sheets with the door frames because of too small or an insufficient number of bolts, or because the designer failed to realize that a bolt put in place in the field may not make as efficient a joint as can be obtained in the shop with the same fastening. The entire bursting pressures below the top of the bin door are transmitted to the door frame, and this feature must be of heavy enough construction to prevent noticeable deflection. Some prefabricated bins now on the market are weak in this respect.

The design of wooden bins for strength is well covered in Farmers' Bulletin 1636, "Farm Bulk Storage for Small Grains," and in "Wheat Storage in the Ever-Normal Granary." These publications include tables giving the safe size and spacing of studs and joists for farm grain bins of various depths, and the safe loads for various sizes and spans of joists.

WEATHER TIGHTNESS

An otherwise well-constructed bin, filled at harvest with good dry wheat, may not safely store the grain because of failure to keep out rain and snow. Rain driven by wind will enter a bin through small holes in the roof, cracks in the walls, and around ventilators, or at the floor line in some types of construction. Rain leaking in through a hole in the roof will usually run straight down to the floor, resulting in a core of spoiled wheat under the roof opening, and a spoiled condition of the grain on the floor which may be attributed to some other cause. It has been found in the northern states that it is sometimes more difficult to make a bin tight against snow than against rain. Experimental bins at Fargo that were wellbuilt and excluded rain, allowed several inches of snow to blow in on top of the grain in one blizzard. If the snow is shoveled out before it melts, it of course does little harm, but it must be remembered that it may melt under the roof before it does on the ground. Our engineer at Fargo observed snow melting on a bright day in a metal bin at an outside temperature of –2 F. The water from such slow melting causes an increase in moisture content of the wheat in the upper layers. A certain amount of it may run down the wall to the floor. Another source of trouble from snow may occur in the spring when drifts against the south side of the bin begin to melt sooner than the snow farther away, the trapped water running into the

[3]Ketchum, Milo S. The design of walls, bins, and grain elevators.
[4]Long, J. D. The design of grain storage structures. Agr. Engr. 12:7 (July 1931).

joint between the side walls and bin floor. The remedies for the above failures are obvious — make all joints in bin walls and roof weather tight, using caulking compound if necessary; close ventilators in winter months by plugging with burlap sacks, and build bin on a foundation high enough to give proper drainage.

INSECT CONTROL

The Bureau of Entomology and Plant Quarantine states that millions of dollars are lost yearly by farmers because of damage to stored grain by weevils and the Angoumois grain moth. This past year the engineer in charge of the storage investigations at Hays, Kansas, made a survey of farm wheat bins in the eastern and central sections of that state. In July, shortly after harvest, samples were obtained from 49 bins, the wheat moisture contents ranging from 10.4 to 17.3 per cent. No insects were found at that time. In the latter part of September, about two months later, 22 of the bins around Wichita were revisited and sampled, and 18 were found to be infested with bran bugs and flour worms, 11 severely enough to be graded weevily. Only one of these bins was under seal for a loan.

Insect loss after the grain is in storage can be prevented by fumigation. The usual method is to use a heavier-than-air gas that will penetrate down through the grain mass. It is necessary that the bin walls and floor be tight, the effectiveness of any fumigant being in inverse proportion to the number of cracks and openings.

BIN VENTILATION

Damage to damp wheat in storage is usually caused by the activity of microorganisms and by excessive respiration of the wheat kernel. Heat is evolved by the microorganisms and by kernel respiration at a rate depending to a large extent on the wheat moisture content and temperature. Where the heat generated is not removed promptly, it will raise the wheat temperature and increase the rate of respiration, this self-accelerating process continuing until the grain is unfit for human consumption. Insect infestation also may, in addition to the damage caused by the actual feeding upon the kernel, produce enough heat and moisture to start this self-accelerating process. Therefore, in designing ventilated structures for the safe storage of damp wheat, in addition to insect control two problems must be solved —the dissipation of heat and the removal of moisture from the wheat. Both must be accomplished before material damage has occurred.

Excess heat evolved may be transferred from the wheat mass to the bin wall by conduction or radiation, and then to the surrounding air, or may be removed by convection currents of air. Tests made in connection with this investigation by the National Bureau of Standards indicate that for wheat with a moisture content between 12.5 and 14 per cent, the thermal conductivity varied from 0.89 to 0.98 Btu per degree Fahrenheit per hour per square foot per inch thickness. This means that wheat as an insulator is about as effective as sawdust, and will resist the transfer of heat from the wheat mass to the bin wall. Many temperature readings taken by means of thermocouples in the wheat mass have shown that, where conduction and radiation alone are depended upon, the removal of heat from a large bin of damp wheat is not fast enough to prevent the building up of temperatures dangerous for safe storage. The amount of heat transfer by conduction may be increased by shortening the distance of heat travel, and this method is used in some types of bin ventilating systems. However, for rapid removal of heat from large masses, air flow through the grain is necessary.

Air flow is also necessary for the drying of wheat, the rate of moisture removal depending upon the amount and condition of air, wheat temperature and moisture content, and length of air travel through the wheat. In bins with tight walls and bottoms and with no ventilating flues or other equipment, we have found little change in wheat moisture content, except in the top six inches or one foot, even though a ventilator is fitted into the roof to provide air circulation above the grain.

The problem of bin ventilating system design is complicated by the fact that air movement is necessary for ventilation but a hindrance to insect control. Any openings in the sides or bottom of a ventilated bin must be so arranged that they can be easily sealed when necessary to fumigate.

WIND-OPERATED VENTILATING SYSTEMS

The higher average wind velocities and lower relative humidities make natural or wind-operated ventilating systems more effective in the area west of the Mississippi River than in the more humid sections farther east. Two systems, both utilizing the pressure developed by the wind, were tested at Fargo, North Dakota, and Hays, Kansas, and found to store wheat safely with an initial moisture content of from one to two per cent higher than could safely be stored in unventilated bins in the same areas and appear to be practical for use on the farms in those sections. These systems also allow fairly easy sealing of the bins for fumigation.

Both designs have a large cowl, throat diameter about 12 in, above the bin which is kept headed into the wind by a vane. Wind pressure forces air from this cowl into a round pressure chamber, covered with screen or perforated metal, in the center of the wheat mass. In a 1000-bu round bin 14 ft in diameter and 8 ft high, the air chamber or drum used is about one foot thick and 7 ft in diameter. The bin floor must be of screen or perforated metal, so that the drying and cooling air can leave at both the top and bottom of the bin after traveling through $3\frac{1}{2}$ ft of wheat. The advantage of introducing the air at the bin center and forcing it out through the top and bottom surfaces of the wheat is twofold: (1) The cool dry air will first cool and dry the center of the mass where trouble from heating and molding is first likely to develop, and (2) any increase of wheat moisture content due to deposition of moisture on cool wheat will occur near the bottom or top of the bin where it may more easily be picked up by the outside air. By banking earth around the bottom of the bin and closing the one duct leading from the cowl to the drum, the wheat stored in a bin of this type can be effectively fumigated.

The second design is more suitable for installing in a wooden bin. Air from the pressure cowl is led to two layers of flues, one layer at the floor level and the other two-thirds of the distance up from the floor. These flues, of 1x4-in boards on edge, about 4 in apart and covered with fly screen, should be spaced horizontally about 2 ft on centers. The ends of the flues not connected to the cowl are closed. A third layer of flues, half way between the two inlet layers, serves as an exit for part of the ventilating air, the remainder passing out through the upper surface of the wheat. Both ends of the outlet flues are open to the air. By pasting paper over or otherwise closing the ends of the outlet flues and closing the large duct leading to the pressure cowl, this type of bin can also be effectively fumigated.

Either of the above described ventilating systems can be easily adapted to power ventilation by replacing the pressure cowl with a blower. If a blower of adequate capacity (1 to 1.5 cu ft of air per min *(Continued on page 476)*

Weed Control in Western Canada

By Evan A. Hardy
MEMBER A.S.A.E.

WEEDS growing in crops have in less than fifty years become the major concern of the agriculturists of western Canada. Weed seeds came into western Canada with the earliest settlers, in cattle cars, with poorly cleaned seed and with the wind and birds. Practically every weed perennial or annual which is at all suited to the soil, moisture, and general climate of western Canada has been established and is a threat to the yield and quality of all crops grown on the prairies.

Loss to the prairies in crops shipped out to the terminal elevators for the 1938 crop was 2.12 per cent, 7,341,378 bu, or 183,534 tons of dockage. This volume is equal to 111 train loads of 50 cars each, which was transported from all over the prairies to the terminals. The freight alone on this volume at the lowest estimate amounts to $734,137.

Production of one bushel of dockage has been conservatively estimated as being equivalent to from 2 to 5 bu of grain. Weeds compete with crops for soil moisture and plant food in no uncertain way. The research work at the Dominion Experimental Farm at Swift Current, Saskatchewan, has shown that the influence of weeds on the yield of grain is probably next in importance to the moisture supply.

DEEP PLOWING UNDER OF SEED ONLY POSTPONES PROBLEM

Many methods of weed control have not been based on fundamentally sound weed culture. Many annual weed seeds have been plowed down, only to wait for years to be brought up again so that germination was possible. Deep tillage has been a menace to weed control. Shallow plowing with shallow cultivation has proven to be the only method of working the land which is effective year after year.

With the adoption of shallow tillage, sharp and well-adjusted implements are essential to produce high quality work by which no weeds are left. Complete tillage such as the black summer fallow or the finely worked spring and fall tillage must be done in such a way as to cause little pulverization. Excessive pulverizing is sure to cause soil drifting. Soil drifting in the semiarid sections of western Canada has become a hazard which must not be overlooked. Consequently associated with tillage for weed control must also be tillage which will leave the land resistant to the action of the wind.

Perennial weeds are usually controlled during summer fallow by means of shallow tillage plowing or one-way disking so that all of the roots are cut, and the tops are either buried or dried out. The land is then worked some with a disk, cultivator or rod weeder sufficient to prevent any growth above the surface for the rest of the year.

In the case of Canada thistle, the weed grows until in the blossom, when it is mowed, burned, the land plowed or one-wayed 4 in deep, after which it is worked so that no surface growth develops throughout the rest of the year.

Annual weeds are controlled by the green summer fallow method, usually with a light fall disking to slightly cover the weed seeds. Where the weed seeds are mostly mustard, French weed, or Russian thistle, the fall tillage should be light, from ¼ to 1 in and not more. It is of vital importance that the small seeds not be covered too deeply for germination. In the spring, the weeds should be grown until in leaf and about 5 in high. The weeds should be completely killed by shallow tillage, the land packed, and left until the second crop of weeds develops, after which shallow tillage must be repeated. In this way, five or six crops of weeds may be killed in one year, assuming that moisture conditions are at all normal.

The land must not be worked deeper than 4 in, and yet must be thoroughly worked without excessive pulverization. The moldboard plow, when sharp and scouring, is one of the best implements for weed control. The power cost for the plow is not much greater than the cultivator or one-way disk for work 4 in deep. The one-way disk must be sharp and drawn at a speed which will cause the least pulverizing if it is to be used in soils subject to soil drifting. The disk harrow must be sharp and loaded sufficiently to do complete cutting. Much poor quality work has been done with the disk harrow, which in some measure is responsible for the increase in weed infestation. The cultivator, both duckfoot and spring-tooth, must be sharp and fitted with shovels which overlap to give a complete cut and kill. The cultivator is a valuable implement in the areas where soil drifting is a menace, since a complete weed cut can be had without pulverization. The blade cultivator has been developed for the dry semiarid sections of Saskatchewan and Alberta. It may use a straight convex blade or the V flat blade. The advantage of this type of cultivator is the complete cut of all weed roots without pulverization. Rod and cable weeders have been developed and used because of the weeds left in the field after the use of the duckfoot cultivator and the disk harrow. Every weed must be cut off in order to make effective weed control possible.

Research has developed to such a point in the fundamental science of weed growth that complete and effective control is known and can be had, provided that implements are conditioned and operated in such a way as to produce a complete kill of weeds.

A contribution of the A.S.A.E. Committee on Weed Control (1939-40). Abridged. Author: Professor and head of the agricultural engineering department, University of Saskatchewan.

Research Work in Wheat Storage

(Continued from page 475)

per bu of wheat) and a few hours of reasonably dry weather are available each day, as is usually the case in the western wheat areas, such systems should dry wheat of 18 per cent moisture content without damage.

At Hays, Kansas, bins with perforated floors but without means for forcing air through the wheat were effective for equalizing moisture between wet and dry layers; however, they removed very little moisture. They probably do not raise the safe average initial moisture content by more than 0.5 per cent, and are not recommended for the soft red winter wheat area. The efficiency of such a ventilating system can be considerably increased by adding a suction cowl on the roof of the bin and tightly closing all openings above the wheat. In western Kansas the cowl will probably raise the safe storage moisture content 1 to 1.5 per cent higher than for wheat stored in non-ventilated bins, but its effectiveness in regions of high humidity is limited.

Terrace Dimension Changes and the Movement of Terrace Ridges

By L. H. Schoenleber
MEMBER A.S.A.E.

THE perpetuation of an efficient terrace system is due in part to adequate terrace maintenance. If desirable terrace cross sections are to be maintained, proper maintenance will be required. Suitable terrace cross sections may be maintained either by proper farming or by rebuilding the terrace periodically.

A study has been conducted for eight consecutive seasons at the experiment station of the U. S. Soil Conservation Service near Clarinda, Iowa, to determine the movement of the terrace ridge and the yearly change of the following terrace dimensions: (1) Terrace channel cross sections, (2) terrace ridge height, (3) terrace ridge width, (4) vertical interval, and (5) horizontal interval (Fig. 1).

There are many factors which may cause terrace dimensions to vary from year to year. Some of these factors are type of soil, slope of land, crops grown, and farming operations performed. It was impossible during this study to determine the effect of each factor; however, measurements were made which showed the effect resulting from the farming practice used at this station. In nearly every case, the type of crop grown governed the type of operations which were performed. The slope of land upon which terraces were built ranged from 6 to 11 per cent.

Two different methods were employed to obtain the data in this study. Terrace cross sections were made on nearly 10 mi of terrace at each 100-ft station and elevations taken at low point in channel and high point of ridge at each 50-ft station. The second method used was to determine elevations at one-foot intervals on established soil movement lines. Nearly 4,000 ft of soil movement lines were established at right angles to terrace ridges, or running from the top to the bottom of the slope. Elevations were taken to the nearest 0.1 ft for the cross-section survey and to the nearest 0.01 ft for soil movement lines.

Results of Terrace Dimension Changes. Terrace dimension changes resulting when different crops were grown were governed mainly by the types of farming operations which may be performed at that time. An average of the various terrace dimension changes obtained during successive years, and the major tillage operations performed, are shown in Table 1 for each crop grown during an 8-year period. The greatest change in average terrace cross section occurred during 1935 when first-year corn was grown. In every case when terraces were plowed and planted to corn, the average terrace cross section increased. When oats were grown, a decrease for the terrace cross section resulted. This, no doubt, resulted from the method of disking terraces. In general, the average ridge height, when different crops were grown, was affected in about the same manner as the average terrace cross section. The relative magnitude and trend of the differences for average ridge height for the various crops were about the same. However, during 1936 there was a slight decrease for the average cross sections. The tillage operations which induced a change in terrace cross section were no doubt the same operations which caused changes in average ridge height. Relative difference in average ridge width was small after the first year. Average vertical interval and average horizontal interval showed small changes, and in some cases no changes, during the period the above crops were grown.

Averages of the various terrace dimensions for progressive rotation cycles are shown in Table 2. The major tillage operations performed during each progressive rotation are shown in Table 1. In general, tillage operations performed were nearly the same for each progressive rotation cycle. For the first four progressive rotation cycles, the average vertical interval and horizontal interval were the only dimensions which did not show a gradual and consistent increase. The fifth progressive rotation cycle showed a much smaller average cross section and average ridge height. This may have been due to the method of disking during 1936 and 1937. There was practically no change in average vertical interval for all progressive rotation cycles. No change resulted in horizontal interval as the progressive rotation cycles continued.

Terrace dimension changes shown in Tables 3 and 4 were determined from the terrace cross-section survey. These changes showed the same general trend in nearly every case as changes determined from the soil movement survey. There was a change, however, for terrace cross section in 1933 and 1934. Also there was a different trend for terrace cross section for the fifth rotation cycle.

Movement of Terrace Ridges. The movement of terrace ridges with respect to other terraces on a slope may be determined from the tables already referred to. Very small differences in vertical interval and horizontal interval were shown when different tillage operations were performed. In many cases there were no changes. This indicates that terrace ridges on a hill slope do not change their relative location with respect to each other. Measurements of dis-

Presented before the Soil and Water Conservation Division at the fall meeting of the American Society of Agricultural Engineers in Chicago, Ill., December 5, 1940. Author: Assistant agricultural engineer, Soil Conservation Service, U. S. Department of Agriculture.

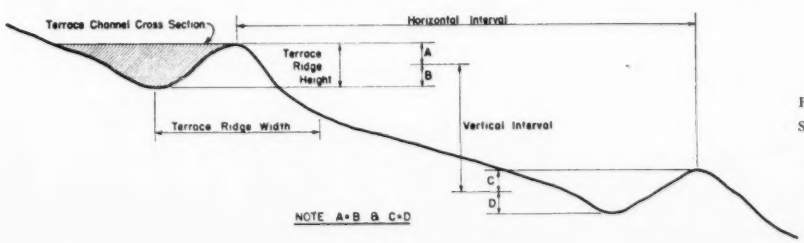


FIG. 1 TYPICAL TERRACE CROSS SECTIONS SHOWING DIMENSIONS REFERRED TO IN THIS STUDY

TABLE 1. EFFECT OF DIFFERENT CROPS AND MAJOR TILLAGE OPERATIONS PERFORMED, ON THE VARIOUS TERRACE DIMENSIONS

(Rotation: corn, corn, oats and seeding of clover, clover)

Average dimension changes for soil movement lines A-A, B-B, C-C, D-D, M-M, and Z-Z (new and old)	1932	1933	1934	1935	1936	1937	1938	1939
	Complete Rotation					Complete Rotation		
	Second-year corn	Oats and seeding of clover	Red clover	First-year corn	Second-year corn	Oats and seeding of clover	Sweet clover and seeding of oats	First-year corn
Change in average cross section, sq ft	3.81	—0.61	—0.35	4.03	0.58	—3.32	0.14	0.02
Change in average ridge height, ft	0.25	—0.03	—0.04	0.28	—0.03	—0.22	0.0	0.07
Change in average ridge width, ft	1.5	—0.1	—0.1	0.6	0.1	—0.2	—0.1	0.8
Change in average vertical interval, ft	0.02	0.0	0.0	—0.02	0.04	—0.02	0.0	0.03
Change in average horizontal interval, ft	—0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
	Tillage Operations							
	Plowed		None		Disked	Disked	Drilled clover and oats	
		Disked at angle			Disked at angle	Disked at angle		
	Disked			Plowed	Plowed			Plowed
	Harrowed at angle	Harrowed at right angles		Disked	Harrowed			Harrowed
				Harrowed	Disked			Disked
	Loose ground listed			Loose ground listed	Loose ground listed			Loose ground listed
	Rotary hoed				Rotary hoed			Double harrowed
	Cultivated 3 times	Drilled oats		Cultivated 3 times	Cultivated 3 times	Drilled oats		Replant corn
	Plowed					Rolled	Rolled	Cultivated 2 times

NOTE: All tillage operations which were not performed parallel to the terrace ridge are indicated. A two-way plow was used during 1935 and all following years. Sign (—) means a decrease in actual dimension from the previous year.

tance from the highest bench mark to the top of the first terrace ridge have been made on four soil movement lines for nine consecutive years. These measurements are shown in Table 5. It is apparent from these data that no significant change in measurements resulted. Inasmuch as there are no significant changes in measurements, it may be assumed that the top terrace ridge does not change its relative location with respect to the permanent bench mark.

CONCLUSIONS

1 Terrace dimension changes when different crops are grown, are due primarily to the methods and type of tillage operations performed.

2 Average terrace cross section will probably increase when all tillage operations are performed parallel to the terrace ridge and when plowing is performed by backfurrowing to ridge, leaving deadfurrow in the channel and throwing all furrows up hill.

3 The two different surveys employed to determine terrace dimension changes proved satisfactory; however, only two dimensions, terrace cross section and terrace ridge height, could be determined from the terrace section survey.

4 Terrace ridges do not creep down the hill slope and do not change their relative locations with respect to other terraces, under farming practices similar to those used.

5 When proper farming practices are performed, adequate terrace cross sections can be maintained which will alleviate the necessity of separate operations to maintain or rebuild terraces.

TABLE 2. AVERAGE OF TERRACE DIMENSIONS FOR PROGRESSIVE ROTATION CYCLE

(Rotation: corn, corn, oats and seeding of clover, clover)

Average of all terrace dimensions on soil movement lines A-A, B-B, C-C, D-D, M-M, Z-Z (old and new)	Average for progressive rotation cycle 1st	2nd	3rd	4th	5th
Cross section, sq ft	16.32	17.23	17.47	17.82	17.17
Ridge height, ft	1.40	1.45	1.45	1.46	1.41
Ridge width, ft	18.4	18.6	18.8	18.8	19.0
Vertical interval, ft	4.58	4.58	4.58	4.58	4.59
Horizontal interval, ft	53.0	53.0	53.0	53.0	53.0

NOTE: Major tillage operations performed are shown in Table 1.

EDITOR'S NOTE: This paper is a brief resume of a more detailed presentation of the same subject, copies of which in mimeograph form may be had on request to the Soil Conservation Service, U. S. Department of Agriculture, Washington, D. C.

TABLE 3. EFFECT OF DIFFERENT CROPS AND FARMING OPERATIONS ON TERRACE DIMENSIONS

(Rotation: Corn, corn, oats and seeding of clover, clover)

Average change for all terraces, Fields A, B, C, and Z	1932 Second-year corn	1933 Oats and seeding of clover	1934 Red clover	1935 First-year corn	1936 Second-year corn	1937 Oats and seeding of clover	1938 Sweet clover and seeding of oats	1939 First-year corn
Change in average cross section, sq ft	2.0	0.6	0.0	3.5	1.9	—5.1	1.2	2.7
Change in average ridge height, ft	0.2	—0.2	0.0	0.3	—0.1	—0.2	0.0	0.1

NOTE: Sign (—) means a decrease in actual dimension from the previous year. All major tillage operations performed are shown in Table 1.

TABLE 4. AVERAGE OF TERRACE DIMENSIONS FOR PROGRESSIVE ROTATION CYCLE

(Rotation: corn, corn, oats and seeding of clover, clover)

Average of all terrace dimensions	Progressive rotation cycle 1st	2nd	3rd	4th	5th
Cross section, sq ft	17.5	19.0	19.1	19.5	19.6
Ridge height, ft	1.5	1.5	1.5	1.5	1.5

NOTE: Major tillage operations performed are shown in Table 1.

TABLE 5. MOVEMENT OF TERRACES DOWN THE SLOPE

Soil movement line	Terrace	Distance, in feet, from highest bench mark to the top of ridge of first terrace 1931	1932	1933	1934	1935	1936	1937	1938	1939
A-A	C-16	*	110	110	110	110	110	110	111	109
B-B	C-1	59	58	58	58	57	57	57	57	57
C-C	C-1	59	59	59	59	58	59	59	59	59
D-D	C-16	120	119	118	118	118	119	118	118	119

*First measurement on A-A line was taken in 1932.

Runoff from Small Agricultural Watersheds

By David W. Cardwell
JUNIOR MEMBER A.S.A.E.

EXTENSIVE operations of various agencies in the field of soil and water conservation and flood control during the past several years stress the pressing need for more adequate runoff data to serve as a basis for planning and design. Present practice generally involves the use of what is called the rational method for computing runoff, employing coefficients developed by C. E. Ramser[1]*. Certain modifications have been made of the original method, in some cases applying data collected at the erosion experiment stations. Engineers of the Soil Conservation Service in the Southeast are using a standardized procedure set forth in a bulletin distributed by the regional engineering division[2]. It is now generally recognized that the coefficient C used in the rational formula, $Q = CIA$, does not properly express the law of surface runoff and that coefficients for various soils, slopes, and cover conditions are lacking. Yet, since no alternate formula has been proposed which suits the need of field operations, engineers find it necessary to continue using the coefficient C.

The Soil Conservation Service in cooperation with state agricultural experiment stations has entered into a joint program to obtain information that will help to solve the runoff problem. Directing these studies, D. B. Krimgold has explained in some detail their general features and methods employed, in AGRICULTURAL ENGINEERING for October 1938.

In the southeastern region, Soil Conservation Service demonstration projects at Danville, Va., and Americus, Ga., were selected for the studies reported in this paper**. Table 1 presents some of the principal characteristics of each watershed.

Results available for analysis are limited to the period of August 1, 1938 to September 30, 1939. Records from the Americus watershed No. 2 prior to January 1, 1939, are omitted because the boundaries of this area were not clearly defined before that date. It is dangerous to draw final con-

Presented before a meeting of the Southern Section of the American Society of Agricultural Engineers at Birmingham, Ala., February 7, 1940. (Abridged.) Author: Assistant agricultural engineer, hydrologic division, Soil Conservation Service, U. S. Department of Agriculture.

*Superscript figures indicate references in the bibliography at the end of this paper.

**A more detailed discussion of importance and methods is presented in a report of a similar project, entitled "Preliminary Analyses of Runoff Data from the Edwardsville Project," by W. W. Horner, in AGRICULTURAL ENGINEERING for June 1940.

TABLE 1. WATERSHED CHARACTERISTICS

Watershed	Acreage	Prevailing slopes,[a] per cent	Soil types, per cent	Land use 1938, per cent	Land use 1939, per cent	Average length of terraces, ft[d]
Danville, Va. W-1	13.4[b]	7, 12	71 Madison V.F.S.L., 14 Madison C.L., 11 Louisa C.L., 4 Louisa V.F.S.L.	32 com. lespedeza, 24 alfalfa, 22 red clover, etc. 4 grass, 3 woods	76 corn & peas,8 tob. 7 lespedeza, 5 grass, 4 woods	720
W-2	16.1	5, 6, 8	47 Mayodan S.L., 29 Granville F.S.C.L., 10 Cecil C.L., 8 Appling S.L., 6 Wadesboro C.L.	43 idle (weeds) 41 tobacco, 12 corn, 2 com. lespedeza, 2 grass	50 tobacco, 24 idle (weeds), 10 wheat, 8 corn, 7 com. lespedeza 1 peas	470
W-3	17.1	4, 7	40 Appling S.L., 35 Durham S.L., 19 Cecil S.C.L., 6 Seneca L.	60 idle (weeds) 31 tobacco, 7 woods, 2 grass	71 tobacco, 20 idle (weeds), 7 woods, 2 grass	420
Americus, Ga. W-1	23.5[c]	1, 4, 6	84 Norfolk sandy loam 12 Ruston sandy loam 4 Gilead sandy loam and clay loam	83 corn & velvet beans 17 cotton	56 corn and velvet beans, 44 cotton	850
W-2	42.8	2½	49 Norfolk sand 40 Ruston loamy sand 3 Ruston sandy loam 8 Orangeburg S.L. and C.L.	79 corn, 17 young forest planting, 4 idle (weeds)	70 corn and peas 17 young forest planting (pine)	790
W-3	32.0	3, 5	55 Ruston sandy loam, deep phase 22 Orangeburg sandy loam 19 Orangeburg sandy loam, deep phase 2 Ruston sandy loam 2 Norfolk sand	52 seeded cowpeas and vol. crotelaria 8 two-year-old pine forest planting, 40 vol. cowpeas	92 idle (grass, weeds), some vol. crotelaria) 8 three-year-old forest planting (pine)	800
W-4	59.2	0, ½	50 Greenville sandy loam 42 Greenville loam 5 Cope loam 3 Red Bay sandy loam	57 idle (Johnson grass), 14 cotton, 12 corn, 12 peanuts, 5 road (sand clay)	32 wheat and hay, 31 cotton, 24 peas, 8 peanuts, 5 road (sand clay)	Unterraced

[a]Slopes which prevail on a large portion of the watershed (30 per cent of the area or more).
[b]Prior to Jan. 1, 1939 acreage was 14.3; 0.9 acres undesirable land diverted at this time.
[c]Prior to Dec. 1, 1938 acreage was 17.9; 5.6 acres desirable land added at this time by reversing terrace grades.
[d]Terraces are variable-grade drainage type.

clusions from data covering so short a period because the trends apparent therein may have resulted from abnormal conditions not yet detected. In addition, without a thorough evaluation of important factors such as soil differences, watershed physiography, and antecedent precipitation, conclusions are likely to be grossly in error. However, since runoff measurements have never before been obtained from small agricultural watersheds, either in the Piedmont tobacco section, or in the Middle Coastal Plain, some preliminary observations on the data will be presented in an attempt to point out the more evident trends and to show the practical use to which future results may be applied.

Use of runoff coefficient C in the rational formula, $Q = CIA$, for computing runoff has been criticized mainly because this coefficient expresses the rates of runoff in terms of a uniform rainfall intensity, whereas the rates of runoff should properly be related to the residual rainfall (that falling after depression storage and surface detention have been satisfied) occurring at rates in excess of the rate at which the water enters the soil. This rational formula is based upon the hypothesis that, during a fairly constant rainfall intensity, the rate of runoff will build up to a maximum in whatever length of time is required for all parts of the watershed to contribute to the flow. This period is called the time of concentration of the watershed.

An analysis has been made by the rational formula, of the highest runoff producing storms yet experienced on the watersheds. A few cases where incomplete records were obtained (because of clock stoppage, pens failing to ink, etc.) have been eliminated, as well as several storms which were evidently of insufficient duration to allow runoff to collect simultaneously at the gaging station from all portions of the watershed. The time of concentration has been taken, in each case, as the difference between the time of beginning of runoff and the time of peak discharge. (In some instances the time of beginning of the peak rise was used where continuous flow existed previously.)

This would give the true time of concentration for any given rainfall intensity and channel conditions, provided the intensity is practically uniform and that it continues as long or longer than the time of concentration. From this it is obvious that there would be very few rains that would satisfy the conditions required for the determination of the true time of concentration. Runoff coefficients have been computed by the rational formula,

$$Q = CI, \text{ or } C = \frac{Q}{I}$$

where Q is the peak discharge in inches per hour from the watershed as measured at the gaging station, corrected for pondage, C is the coefficient of runoff, and I is the average rainfall intensity in inches per hour during the time of concentration (period of runoff rise). The drainage area, A, usually given with this formula has been eliminated by expressing rate of runoff directly in surface inches per hour which is approximately identical with cubic feet per second per acre.

Tabulations from the storms analyzed show, for both localities, considerable range in the values obtained for time of concentration and runoff coefficient for each watershed, no doubt due to non-fulfillment of the requirements for determination of true time of concentration. In the case of the Danville data, appreciable antecedent rainfall appears to result in higher runoff coefficients, as well as reductions in the amount of rainfall abstracted before runoff begins (initial abstraction).

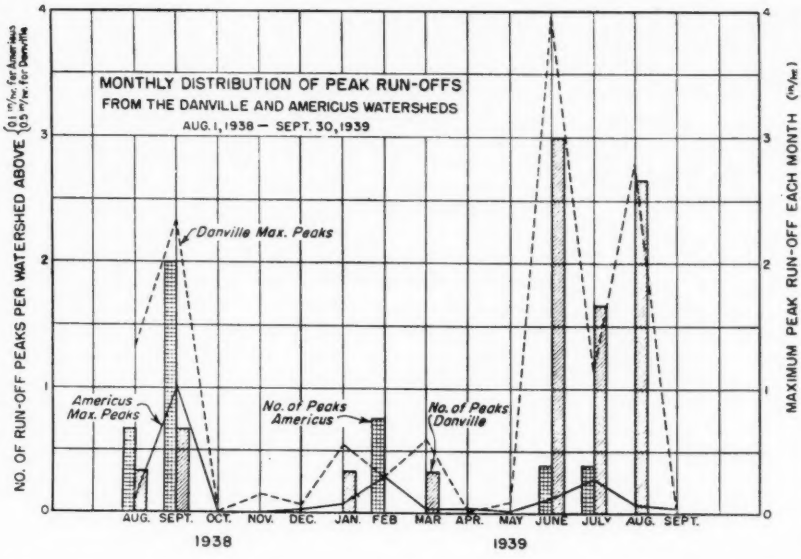
On the Americus watersheds, the effect of antecedent precipitation seems of less importance, possibly because of more rapid rates of percolation through the coarser textured subsoils. After making allowances for the influence of differences in antecedent rainfall, there appears to be a marked tendency for the time of concentration to vary inversely and the runoff coefficient to vary directly with the rainfall intensity. Such a relation is logical because it is the rain falling at rates in excess of the rate at which the water enters the soil which is available for runoff, and this larger rate of runoff, in turn, increases the velocity of flow, thereby reducing the time of concentration. These variations with rainfall intensity point out the many factors which must be considered in the application of the rational formula. Nevertheless, when it is considered that application of the method requires initial selection of one specific design rainfall intensity, the practical importance of these inconsistencies diminishes.

Now, because of the variations detected within each of the tabulations, it will be difficult to compare, and explain, the runoff capabilities of the various watersheds simply from these data. The fact that six of the seven watersheds represent individually arranged terracing systems adds another complication not easily evaluated. Even so, the consistent wide difference between the coefficients obtained for the Danville watersheds and those for the Americus areas is striking. Since, in general, Coastal Plain Soils have a more open structure than those of the Piedmont, it was expected that the former would tend to be considerably more absorptive, but the degree of this difference here discovered comes somewhat as a surprise. The values of the runoff coefficients for the two localities may be of some help to engineers designing for conditions similar to those represented.

ANALYSIS OF RUNOFF DATA

In the field of scientific hydrology several promising schemes for analyzing runoff data have recently been advanced. Foremost among these is Horton's[3] "infiltration theory" which offers an analysis of the hydrograph separating the disposition of rainfall into its principal components, namely, initial detention, surface detention, infiltration, channel storage, and finally surface runoff. Ultimate studies of the Danville and Americus records will involve the preparation of hydrographs of all principal storms which will be subjected to analysis by this or other similar methods. Special consideration will have to be given to results from terraced areas, evaluating the hydraulic features of flow in the terraces as well as in the outlet channels.

In order to contrast the runoff characteristics of the Piedmont watersheds and those in the Coastal Plain, hydrographs of the storms which produced the highest rate of runoff yet recorded at Danville and at Americus have been prepared. Danville watershed No. 2 on June 13, 1939, and Americus watershed No. 1 on September 9, 1938, were almost exactly the same size and might be considered reasonably comparable, with the exception of their wide difference in average terrace length, which is an indication of dissimilar shape. Even though the Americus storm was more severe, in all respects, than the one at Danville, it produced a peak discharge of only 1.03 in per hr compared to 3.94 in per hr for the latter, less than one-third as great. In considering this it should be noted that the Americus storm followed approximately a month's drought, which may have enabled the soil to reach its maximum infiltration capacity. As mentioned previously, however, present records do not indicate that antecedent precipitation is of primary importance in the case of sandy Coastal Plain soils. This September 9, 1938, storm at Americus falls well above


MONTHLY DISTRIBUTION OF PEAK RUN-OFFS
FROM THE DANVILLE AND AMERICUS WATERSHEDS
AUG. 1, 1938 — SEPT. 30, 1939
NO. OF RUN-OFF PEAKS PER WATERSHED ABOVE .01 c.f.s./sq. for Americus .05 c.f.s./sq. for Danville
MAXIMUM PEAK RUN-OFF EACH MONTH (c.f.s./sq.)
Danville Max. Peaks
Americus Max. Peaks
No. of Peaks Americus
No. of Peaks (Danville
AUG. SEPT. OCT. NOV. DEC. JAN. FEB MAR APR. MAY JUNE JULY AUG. SEPT.
1938
1939

Yarnell's[4] one-in-ten-year frequency, both in short-time intensities and in total precipitation for the duration, and yet the total runoff volume amounted to only 0.66 in from the 4.26 in which fell.

The consistently low total runoff from the Americus watersheds for any one storm suggests promising possibilities toward control of all excess water by artificially increasing surface detention by means of such practices as contour-listed furrows and buffer strips. Such applications of these preliminary observations, however, should be avoided at the present time because experience of field men in the Coastal Plain does not substantiate the extremely low rates of runoff thus far recorded at Americus. Furthermore, heavier soil types, such as Greenville and Susquehanna clay loams, may be expected to have much lower infiltration rates than the Norfolk and Ruston sandy loams of Americus watershed No. 1[5].

The low rates of runoff observed from the Coastal Plain watersheds do not necessarily mean that erosion is not a serious problem in this section. On three of the four watersheds such difficulty has been experienced from excessive silt deposition above the gaging stations that special desilting flumes have been installed. It appears that even a small volume of runoff can produce tremendous damage on the uncemented Coastal Plain topsoils. This emphasizes the need for some sort of control which will intercept runoff water before it has a chance to collect and indicates that terraces alone cannot be depended upon to solve the whole problem.

The soils of the Piedmont tobacco section, the majority of which have clay subsoils, inherently tend to be rather impervious. There has been considerable speculation regarding methods which can be employed to increase their absorptivity. The effect of radically different land use may be observed in studying the records of two storms on Danville watershed No. 1. During the year 1938 this area was 85 per cent covered with close-growing crops, but in 1939 it changed to 84 per cent clean tilled crops (corn and tobacco). Although the individual 5-min intensities of the two rains are somewhat different, the maximum 15, 20, and 30-min intensities, as well as the antecedent precipitation, are about the same. When the area was mostly protected by close-growing vegetation, the peak discharge amounted to only 0.19 in per hr, compared to 1.07 in per hr when clean-tilled crops predominated. Comparisons of other runoff producing storms for this area show a similar relation, which difference must be either wholly or in part due to the drastic change effected in land use. The total runoff from the 1938 storm amounted to 8 per cent of the rainfall, whereas the runoff from the storm of the second year was 45 per cent of the rainfall. Difference in total soil loss for the two conditions was undoubtedly greater in proportion because of the added resistance to washing offered by the close-growing vegetation.

A thorough analysis of the two hydrographs will be necessary before discovering in just what manner the vegetation succeeded in retarding surface runoff. Preliminary examination of the 1938 storm's hydrograph would indicate that more was accomplished by the cover crop's ability to hold back the water by means of causing high initial infiltration and surface detention than by materially increasing infiltration after runoff had once begun. It seems to be characteristic of the principal storms thus far recorded for the highest intensities to occur near their beginning, thereby making any measures which can be adopted toward increasing the initial detention period extremely effective.

In this connection, it should be noted that frequent short time high intensities have been experienced without affecting watershed runoff because they were absorbed by initial detention which sometimes becomes unexpectedly large, especially following droughts or periods of cultivation. Present accepted methods of design provide for the use of maximum rainfall intensities of a given expected frequency, presupposing that they will occur at times when antecedent conditions are most conducive to high rates of runoff. Information is needed regarding the conditions preceding and accompanying such intensities to provide design data based on runoff frequency instead of rainfall frequency.

Seasonal variations usually result in "critical" periods for erosion. After runoff records have been collected over a number of years, it will be possible to predict in which calendar months they occur for different climatic sections of the country. Using peak runoff as an index, the accompanying graph shows the highest rate of flow from any one of the Danville and Americus watersheds, respectively, by months. Also given is the number of runoffs with peaks greater than a given minimum per watershed per month. It is assumed that peak discharges below this value cause little erosion, and, with this in mind, it was set considerably lower for Americus than for Danville. Field men engaged in planning might use such charts in order to concentrate control measures for "critical" periods and eliminate young, unanchored vegetative protection during these times.

When more complete results are available from Danville and Americus, it will be desirable to extend their application to other localities. In so doing, careful consideration will be given to such factors as differences in climate, soil, and watershed configuration.

Definite recommendations for practical applications can not be made without further *(Continued on page 482)*

Drainage Problems

THE Committee on Drainage of the American Society of Agricultural Engineers, in furtherance of progress on drainage, recommends that A.S.A.E. members review and consider the need for drainage research, and extend their assistance in securing such research as is needed.

It will no doubt be a surprise to many to know that during the last five-year period there has been less money expended on drainage research and investigation and fewer workers in the field than during any five-year period in the last thirty-five years. This is in direct contrast to interest and support given to other fields of research activities relating to land utilization and development. Many states with large investments in drainage works, and with many problems relating to the maintenance and operation of such works confronting them, devote no funds to drainage research and employ no workers in the field.

If everything worth knowing were known about the subject, if there were no public interest and responsibility for drainage, if there were no problems to be solved—then drainage research might be called a closed book. However, drainage research is not a closed book, there is much to be learned, there is public interest and responsibility, and there are many problems. During recent years, various governmental agencies have spent tens of millions of dollars on drainage work. Sometimes the work was not effective, and it is believed that, had research work been further advanced, many of the drainage jobs would have been more effective. These faults gradually are being corrected and public drainage programs are improving. In some of the work advanced procedure and methods are being used and tried out and much progress is being made. Improved drainage techniques worthy of being copied are proving successful. However, improved practices could be spread, and many of the specific problems could be solved by an adequate research program.

A good research program should be closely allied with actual work programs. The following are some of the problems which the Committee on Drainage believes should be worked on in a drainage research program:

Runoff from Flat Lands of Small Area. Few data are available giving runoff from flat lands of areas less than 2 sq mi, and in some areas this limit may be placed as high as 5 sq mi. Such data should be secured in order to permit proper design of farm drainage systems, head walls, inlet structures for open ditches, and small open ditches and tile systems.

Mole Drainage. Mole drains are constructed by drawing cylinders, usually about 3 to 4 in in diameter, at a depth of 16 to 20 in and from 3 to 5 yd apart, in heavy soils. This type of drainage has been used more widely in Europe than in this country. Since tractor power is available on nearly all farms, this type of drainage could be applied if found beneficial. Little is known about its application and results, and the subject should be investigated.

Depth and Spacing of Tile Drains. More reliable data should be secured on which to base recommendations for depth and spacing of tile drains for various conditions of soils and crops. Surface drains to supplement tile drains and their application to various soils and crops are closely related and should be studied.

Control of Water Table. Some muck and peat soils have been overdrained with disastrous results, as, for example, the Florida Everglades. There fires have resulted in large areas of land being destroyed. In Indiana and Michigan several attempts have been made to control the height of water table in such soils to prevent fires, to minimize blowing of soil, and to provide proper moisture conditions for crops. Investigations are desirable to determine proper methods of control to use under various conditions particularly in peat and muck soils.

Maintenance of Open Ditches. The maintenance of open ditches is an important problem which should receive the attention of research workers. The maintenance practices to be followed on ditches having various side slopes should be determined. The benefits, cost, and limitations of pasturing ditches should be investigated. The vegetation to use on side slopes, the treatment of spoil banks, drainage behind the spoil bank, sources of silt and how to minimize or prevent silting are other physical problems which should be worked on. Equipment to facilitate maintenance and lessen hand labor should be developed. In addition to the physical problems, the problem of responsibility and organization for maintenance should be studied.

What responsibilities should the various governmental units and the farmers affected, respectively, take in a maintenance program? Maintenance of ditches is a big job; under existing conditions how should it be done and who should do it?

State Drainage Laws. State drainage laws, while in some instances unnecessarily complicated, have been effective for organization, financing, and construction of new drainage enterprises. However, many of the laws fail to provide effective means of securing systematic maintenance of existing drainage improvements. The problem of revising state drainage laws should be investigated with a view of decreasing the cost of organizing and administering such enterprises. The problem is not simple due to legal restrictions and court decisions that have been built up over a period of many years. It is believed that a research project in which the legal, engineering, and farmers' viewpoints are represented would be of basic help in improving state drainage laws.

Report of the A.S.A.E. Committee on Land Drainage for 1939-40. J. G. Sutton (chairman), F. F. Shafer, D. A. Isler, B. O. Childs, H. G. Edwards, C. E. Jacoby, Geo. Burnet, J. T. Olson, I. D. Mayer, and E. W. Gain.

Runoff from Small Agricultural Watersheds

(Continued from page 481)

study of the results thus far secured and to be obtained in the future. The preliminary results as discussed, however, serve to indicate the wide differences which may be expected between the runoff capabilities of various problem areas, and to emphasize the need for additional investigation.

BIBLIOGRAPHY

[1]Ramser, C. E. Runoff from small agricultural areas. Rprt. Jour. Agri. Res. Vol. 34, No. 9, May 1, 1927.

[2]Cardwell, D. W. Rainfall and runoff. Mimeo. Soil Conservation Service, Spartanburg, S. C., August 1937.

[3]Horton, R. E. Surface runoff phenomena, Part I. Horton Hydrologic Lab., Voorheesville, N. Y., Publ. 101, Feb. 1935.

[4]Yarnell, D. L. Rainfall intensity-frequency data. USDA Misc. Publ. No. 204, August 1935.

[5]Free, G. R. and Musgrave, G. W. A preliminary report of an infiltration study of some Piedmont and Coastal Plain soils. USDA Soil Conservation Service TP-13, May 1937.

Progress in Contour Furrowing

THE report prepared by the Committee for this year is intended as a supplement to the 1938-39 report, in which a report of progress of contour furrowing in the various sections of the United States during the past year is made.

Much of the data used in the 1938-39 report was received from the U. S. Soil Conservation Service work units. Many of these work units were abandoned during the past year and personnel placed elsewhere. For this reason, it was impossible to obtain repeat observations on those areas for which data tables were prepared in the previous report. Many observations on new and different type areas are in progress or planned for this next year. It is expected that the Committee will be able to make a more detailed report for the year 1940-41 than for this year.

NORTHEAST AREA

Large areas of relatively old contour furrows observed near Clarksburg, W. Va., during the past year indicate that water conserved does benefit vegetation for more than one foot on each side of the furrow. As a result, it is recommended that contour furrows in this area have a maximum lineal spacing of from 6 to 8 ft.

The storage capacity of furrows has decreased as much as 50 per cent in many instances. In order that the effectiveness of these structures might be extended over a longer period of time and that they might be of benefit in reducing flood flows, furrows having a minimum cross sectional area of 2 sq ft are being recommended in this area.

Hillside plows are still used extensively for furrow construction at an average cost of approximately $1.05 per acre. Some trial work with a special furrowing plow is being done in several areas of this section. It is expected that some information concerning results of this work will be available within another year or two.

SOUTHEAST AREA

The use of contour furrows on both new and old pastures to be seeded to grass has become a general recommendation in this section when topography and soil conditions permit. Areas to be furrowed should be comparatively free of stumps and have pervious sub-soils.

The "furrows" consist of beds approximately 10 ft wide thrown up on the contour. Control contour lines should be run approximately 30 ft apart on the steepest part of each field.

Experimental work in contour furrowing has been initiated on the Soil Conservation Service experiment station at Blacksburg, Va. Experimental plots are being established on the North Carolina experimental dairy farm at Statesville, N. C. These plots will be studied in cooperation with the Soil Conservation Service to observe the difference between subsoiling, contour furrowing, and sodding without mechanical aid.

Several years of observation of contour furrows on pasture land in this section have indicated definite trends, as follows:

1 Contour furrows can be built when the land is prepared at little additional expense.

2 Contour furrows definitely prevent erosion, fertility, and seed loss between the time of seeding and complete sod establishment.

3 Contour furrows conserve fertility and seed loss after the pasture is established by preventing concentration of litter and seed in the low places in the field where it would be carried off by excess runoff water if the pasture was not contour furrowed.

4 It is believed, but not yet definitely determined, that the quality and quantity of grass will be increased by contour furrows.

5 Contour furrows may be of value as a flood control measure by reducing excess runoff.

EAST CENTRAL AREA

Contour furrows have not proved valuable as a pasture improvement measure in this section. They have, however, been found to be very beneficial in the establishment of new seedings, renovation of old pastures and holding water from critical areas.

Considerable difficulty has been encountered in the large furrows or ridges breaking over during severe storm periods. For this reason it is planned that smaller furrows placed from 2 to 4 ft apart horizontally will be used and observed during this next year.

At Paducah, Ky., observations indicate that a broad flat ridge type of furrow will largely take the place of other types of furrows in future planning in this area. These furrows are constructed in a similar manner to those in the Southeast. The fields are plowed in a series of narrow lands on the contour. This makes possible the compaction of soil with a soil packer and does not interfere with mowing of weeds and other vegetation.

WEST CENTRAL AREA

For the past two years contour ridges and contour furrows at LeRoy, Ill., have been under observation. In general, these observations indicate that (1) it takes approximately 3 yr to revegetate the ridges; (2) the disturbed areas produce about 75 per cent as much vegetation as the undisturbed areas; (3) in general, lespedeza and alsike are the predominant legumes, with lespedeza predominating on the ridges and alsike in the furrows, and (4) there is an indication of increased production from 3 to 6 ft above and below the furrows.

Observations throughout this section indicate that contour furrows do not contribute to pasture improvement. Their greatest benefit has resulted from use as a gully control measure. In this way they prevent runoff water from reaching small gullies and thus reduce the rate of erosion. It is believed that they can be justified as an erosion control measure much more easily than they can as a pasture improvement or moisture conservation measure.

SOUTH CENTRAL AREA

Cross Timbers Section of Texas. Observations during the past year have indicated the following:

1 On contour furrowed areas a definite decrease was noted in the density of buffalo grass sod. This was evidently due to the fact that pastures involved were stocked lightly. This lack of use caused the buffalo grass to grow more upright rather than spread and increase the sod density.

Report of the A.S.A.E. Subcommittee on Contour Furrowing, of the Committee on Soil Erosion — E. C. Buie (chairman), P. C. McGrew, C. A. Logan, D. D. Smith, G. H. Bingham, J. W. Jourdan, Dale Ryman, J. J. Coyle, I. L. Saveson, Staton McIver, and H. M. Rhodes.

2 Contour furrows should not be plowed deeper than the top soil.

3 Contour furrows can effectively take additional water from outside sources while damage will result if extra water is discharged on contour ridged areas.

4 The contour furrowed area produced 2001 lb of air-dried forage per acre, while the untreated land produced only 1079 lb.

5 The contour ridged area produced 1410 lb of air-dried forage while the untreated land produced 1058 lb. The untreated land, however, produced slightly more grass than did the treated area.

Edwards Plateau of Texas. Observations on range and pasture lands are being conducted on six farms within this area. These observations indicate the following trends during the past year:

A. *Pantograph Studies.*

1 Contour ridging. (a) Plots located above the contour ridge showed a more consistently average ground cover than did plots below the ridge. (b) The average of the six farms studied indicated that above the ridge the more palatable grasses made consistent decreases in ground cover while the less palatable species made slight increases. (c) Most grass species on the ridge remained consistent or showed increases in ground cover. (d) Practically all species on all plots below the ridge showed consistent decreases in average per cent ground cover.

2 Contour listing. (a) Plots having a high per cent ground cover in April showed sharp decreases in buffalo grass; plots having a relatively low per cent ground cover showed increases in buffalo grass. (b) Although contour listed plots showed decrease in average ground cover they still maintained a higher average per cent of ground cover than other types of treatment.

3 Crescent ridges. Observations indicate that practically all species above, on, and below ridges made consistent increases in per cent of ground cover under proper pasture use.

4 Water spreading. Consistent decreases in per cent of ground cover in most species indicated that ground cover can be increased with addition of water. It will, however, be difficult to maintain this increased ground cover under drought conditions.

5 No mechanical treatment. (a) Average per cent ground cover shows a consistent decrease for all species present. (b) Average ground cover is substantially lower on plots receiving no mechanical treatment than on treated plots.

B. *Vegetative Yield Studies.*

1 Mechanically treated areas produced more vegetation than untreated areas.

2 Where all types of treatment were located in the same pasture, contour listing produced more vegetation during the current year than did other types of treatment.

3 Where all measures of treatment were located on the same pasture, livestock grazed more vegetation from the water-spreading area in April, before new growth was advanced. During subsequent periods however, they grazed more from the contour listed areas.

4 Vegetative production can be greatly increased by the addition of extra runoff water, but this increase probably cannot be maintained during extended dry periods.

5 Increases in amount of vegetation produced on treated areas were primarily desirable grass species, with few weed species present.

SOUTHERN GREAT PLAINS AREA

Continued observations on any of the plots studied during the past three or four years has become impossible due to abandonment of work unit areas and reassignment of personnel. No definite observations are available at this time to indicate trends of comparative grass yields on treated areas as compared to untreated areas.

Observations during the past year have continued to bear out the general thought that furrows from 4 to 6 in deep and 10 to 14 in wide consistently produce the best vegetative yields and are most effective as a pasture improvement measure. On shallow soils and where flood control is a primary objective larger furrows are recommended.

Observations indicate that it is not unreasonable to expect an increased vegetative yield on pastures of from 50 to 100 per cent, depending upon density of sod prior to treatment, adjacent blow hazards, and rainfall conditions during the growing season.

During the past year rainfall conditions were poor on some of the areas. The value of contour furrows was definitely indicated in these areas and observations showed that grass growth on untreated areas was too little to make clippings, while furrowed areas produced a sufficient amount of grass to justify clippings. This indicates that during years of low rainfall, and especially where a high percentage of the total annual rainfall comes in showers of high intensity and comparatively short duration, contour furrows may mean the difference between a sufficient amount of grass for summer grazing and the necessity of either reducing the herd or seriously overgrazing the pasture.

NORTHERN GREAT PLAINS AREA

Observations of furrows in this section indicate that furrows of the size made by a lister and smaller lose so much of their water-holding capacity in three to four years as to become almost ineffective. Furrows made with the point of a blade and under observation for the same period of time have grassed over and still have good water-holding capacity.

It has taken furrows at Winner, S. D., three or more years to grass over in most cases. Clippings on observed plots indicate little or no difference in grass yields three years after the construction of furrows. The grass, however, grew taller and remained green longer along the furrows.

At Alcester, S. D., all observations indicate the pasture furrows are valuable as a pasture improvement measure only on overgrazed areas. The furrows help to hold both soil and water until the grass can reestablish itself.

At Huron, S. D., observations indicate an increase in grass production and a decrease in weed production on furrowed areas on slopes, ranging from approximately 2 to 13 per cent. This indicates that the increased moisture made available to the grass by the furrows made it possible for the grass to crowd the weeds out. It is expected that the steeper slopes will be benefitted by furrows to a greater degree during years of high rainfall than will the more level areas.

OTHER SECTIONS

No additional information was available to the Committee from the Southwest.

Very little contour furrowing has been done along the Pacific Coast. This practice does not seem to be very applicable to this section.

In the Pacific Northwest large furrows were originally used on steep slopes for flood *(Continued on page 488)*

Engineering Problems in Grain Storage

By George J. Burkhardt

MEMBER A.S.A.E.

GRAIN storage problems in general can be divided into two parts, namely, harvesting grain fit for storage or conditioning grain to make it fit for storage, and maintaining the quality of grain while it is in storage.

Of the after-storage difficulties, that of insect control varies most. A study of the receipts at the leading winter wheat markets shows that the per cent of weevilly grain received at Baltimore is far in excess of that at any of the other markets. Grain insects become inert at low temperatures, but once they have had a chance to colonize they can maintain temperatures high enough to continue activity throughout the winter. The long period of warm weather between grain harvest and fall, combined with a humid climate, makes the control of insects in Maryland a serious problem.

Many farm bins are not built tight enough to permit effective fumigation, nor do many farmers realize the damage which may occur due to insect colonization in their grain bins. In a large part of Maryland the grain bins are typically located in or adjacent to the farm barn. In these the fire hazard limits the use of the more common, inflammable fumigants. It is common to find farmers selling their wheat when insects threaten rather than attempting to protect it by fumigation.

The most difficult problem in Maryland is the harvesting of grain fit for storage. Recent work at the Maryland Agricultural Experiment Station indicates that wheat of up to 15 per cent moisture content will keep satisfactorily from harvest to the following spring, but that it is likely to turn sour if stored through April. For longer term storage the moisture content must be 13.5 per cent or less. It is also of interest that the movement of moisture within a bin is less at these lower moisture levels. The average annual rainfall in Maryland is slightly over 40 in, of which 8 in fall during the harvest months of June and July.

According to official grain standards for hard red winter and soft red winter wheat, grain of over 14 per cent and not over 15.5 per cent moisture is graded "tough". Fig. 1 gives some idea of the amount of high moisture wheat produced in the areas around the various grain markets. Wheat of over 15.5 per cent moisture is graded "sample grade". A large amount of tough wheat, however, would indicate a proportionately large amount of grain of even higher moisture content. During a five-year period (1934-38), for which data are available, over one-third of the wheat received on the Baltimore market was graded "tough".

While the problem of storing tough wheat in Maryland may be no more difficult than in other sections of the country, there is more to store and the chances of harvesting dry wheat are much less.

Fortunately, Maryland farmers realize the danger of losing wheat of high moisture content and sell immediately any wheat which they feel will not store safely. Such wheat is shipped to Baltimore for drying as only a few of the larger local elevators have drying equipment.

No data are available as to the amounts of high moisture barley and other grains produced annually, but it seems reasonable to believe that the proportions hold. This grain, furthermore, is regularly used as feed on the farm and therefore provides a more serious storage problem. Farmers have said that it is almost impossible to harvest barley satisfactorily with a combine as it breaks down before it is dry enough to store safely.

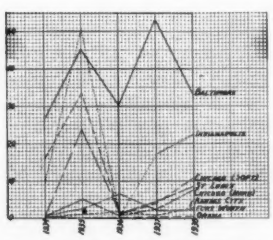
Farm storage is especially difficult for three reasons. Farmers lack equipment or facilities to determine accurately the moisture content of their grain, farm bins lack facilities to determine changes taking place in the bin before serious damage has occurred, and few farm granaries provide facilities for either handling or conditioning grain requiring such treatment.

I do not say that a farmer should or should not store grain for purposes of obtaining higher prices. Sound economics, however, requires that all grain which is used on the farm should be stored there until needed, that all grain which is used locally should be stored either on the farm or in the local elevator to keep down transportation costs, and that grain which does not normally flow through the terminal elevators should not be sent there for drying if the extra transportation costs so incurred can be eliminated.

In 1936 a project was organized in cooperation with the U. S. Department of Agriculture to find a solution to these problems. Present data indicate that (1) no ordinary structure will safely store high moisture content wheat; (2) additions of preservatives do not appreciably improve the keeping quality of wheat, though the addition of lime and sulphur has kept a bin of 15 per cent wheat from souring since 1937 while similar wheat without the addition turned sour in the spring of 1938; and (3) ventilation properly installed will aid in keeping tough wheat, but that it is doubtful whether the expense and inconvenience of the ventilating system are justified considering the results obtained in the humid climate of this region.

With these factors in mind, after a thorough study of the conditions in a mechanically ventilated bin, a new grain drier was developed which is compact enough to provide reasonable capacity in a portable machine. In its elementary parts this drier (Fig. 2) consists of a grain hopper, an air vent, several extended surface heating coils with a diffusion space between them, a *(Continued on page 488)*

Paper presented before the Farm Structures Division at the annual meeting of the American Society of Agricultural Engineers at State College, Pa., June 17, 1940. The author is agricultural engineer, University of Maryland.



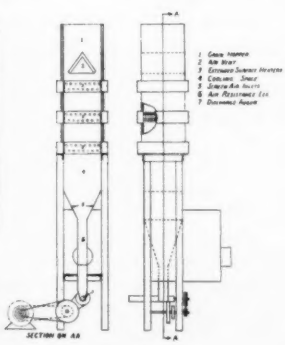


Fig. 1 (Above) Curves showing per cent of tough wheat received at various markets. Fig. 2 (Right) Diagram of grain drier developed at the University of Maryland, showing principal parts

Electrical Weed Control

By E. M. Dieffenbach
MEMBER A.S.A.E.

ELECTRICITY is being used for so many things that it is not surprising that attempts are made from time to time to use it for killing weeds.

In response to requests for information on the subject, the U. S. Bureau of Agricultural Chemistry and Engineering, in cooperation with the Utah agricultural experiment station, has attempted to find out some of the fundamentals involved in the possible use of electricity for weed control. The weed selected for most of the experiments thus far was the *Convolvulus arvensis,* more commonly known as the wild morning-glory, bindweed, creeping jenny, and a number of other aliases. This weed was selected because it is so widely distributed over the United States, and because it is so hard to kill. At this writing the work done on electrical weed control can be listed under four main headings: (1) Measurement of electrical resistance of morning-glory rootstalks, (2) measurement of electrical resistance of soil, (3) treating small pieces of morning-glory rootstalks with different amounts of electricity and planting them, and (4) planting of morning-glory plants in containers for future electrical treatments.

In measuring the electrical resistance, small pieces of rootstalk were used. A form of Wheatstone bridge called a "post office bridge", was used for taking the measurements. The source of current for the bridge was an audio oscillator energized by a 6-volt Edison-cell battery. The oscillator produced a signal with a frequency of 1,000. The oscillator was used to avoid polarization which might otherwise be present when using direct current. An amplifier and speaking system were used in the bridge circuit to determine the null point on the bridge. At the same time, a cathode ray oscilliscope in the bridge circuit gave visual indication of the null point on the bridge.

Resistivity was calculated in ohm-centimeters by the formula $P = RA/L$, where P is the resistivity in ohm-centimeters, R is the resistance in ohms, A is the area in square centimeters, and L is the length in centimeters.

Over one hundred pieces of rootstalk were measured for resistance, the pieces varying as to age, size, and dryness. The resistivity of the rootstalks varied from 1,500 to 5,000 ohm-centimeters, with the mean near 2,500 ohm-centimeters. As a characteristic measurement, one piece 0.25 cm in diameter and 10 cm long had a resistance of 520,000 ohms. Another piece 0.18 cm in diameter and 10 cm long, had a resistance of 1,200,000 ohms.

The purpose of measuring the electrical resistance of soil was to be able to compare its resistance with that of the rootstalks in order to give some idea as to whether electricity when applied will follow weed rootstalks or soil. Only a few soil measurements were necessary to determine which medium would offer lower resistance. Three tests were made: To determine the resistance of dry soil tamped in place; soil a little more moist, not tamped in place; and soil sufficiently moist for planting (at about 16 per cent moisture content).

The dry soil measured for electrical resistance was not oven dried, but was taken from a field of morning-glory where there had been no rain or irrigation for three weeks and the soil was comparatively dry. This soil was tamped into short lengths of glass tubing 8 cm in diameter, with end contacts of mercury pools. Resistivity of this soil varied from 100,000 to 200,000 ohm-centimeters among the samples tested.

For additional tests, the soil was obtained three days after a quarter-inch rain, with the soil still showing moisture. This soil was poured (not tamped) into a cardboard container 21.5 cm in diameter and 52 cm high. Contacts were made by means of screen separators spaced at 15.5 cm. These screens or separators covered the entire cross section of the cardboard container. Under these conditions with the soil loose and not tamped, the soil had a resistivity of from 350,000 to 400,000 ohm-centimeters.

In the moist soil test, the soil had a moisture content of about 16 per cent, about the right moisture content for planting. It was placed in a cardboard container with screen electrodes and was tested in much the same manner as was outlined in the previous paragraph. The resistivity of this moist soil was found to vary from 20,000 to 25,000 ohm-centimeters.

It is realized that the structures of the soil, its chemical content, its moisture content, and similar variables would influence its resistivity. However, it is believed that, with the soil at all dry, the electricity would follow the rootstalks. The dampest soil tested had a resistivity of 20,000 ohm-centimeters, while the resistivity of the rootstalks varied from 1,500 to 5,000 ohm-centimeters, with a mean near 2,500 ohm-centimeters.

About 650 small pieces of morning-glory rootstalk, one to three inches long, were treated with various amounts of electricity, and were planted and watched for growth. About one-half of them were treated with direct current at 150 or 380 volts, and the rest were treated with alternating current at 200, 325, or 700 volts. The diameter of the rootstalks treated varied up to four millimeters. It was found that ten milliamperes was enough to kill any of the rootstalks treated. Reduced to current density, it required as much as 0.2 amperes per square centimeter to kill some of the rootstalks. The young healthy growing roots were least susceptible from the standpoint of the current density required to kill. In general, rootstalks were killed with slightly lower amounts of direct current than alternating current. Differences in voltage had no appreciable effect on the amount of current necessary to produce a kill.

When considering the killing of morning-glory rootstalks on a practical scale, it is a matter of conjecture as to how the lethal current of 0.2 amp per sq cm will need to be applied. Can this current density be figured on the basis of the actual cross-sectional area of the rootstalks in the soil, or must the area be based on the entire area of roots and soil? If the entire cross section of soil must be subjected to this current density, then the current required would be prohibitive.

One hundred and fourteen containers were planted last fall with rootstalks of morning-glory to be used for future electrical treatments. The containers used are made of waxed cardboard and are known in the dairy trade as "bulkans". The bulkans are 21.5 cm *(Continued on page 488)*

A contribution of the A.S.A.E. Committee on Weed Control (1939-40). Author: Associate agricultural engineer, Bureau of Entomology and Plant Quarantine (formerly with the Bureau of Agricultural Chemistry and Engineering), U. S. Department of Agriculture.

Equipment for Chemical Weed Control

By O. C. French
MEMBER A.S.A.E.

THE use of chemicals for controlling weeds in California is finding more favor each year. Requests for information as to equipment for applying the chemicals are increasing.

Types of herbicides being used with success in California are as follows: (1) contact sprays, including diesel oil, Sinox, and sulphuric acid (the latter two also called selective sprays); (2) translocated sprays (acid arsenical material); (3) temporary soil sterilants (carbon bisulphide), and (4) relatively permanent soil sterilants, including sodium arsenite (liquid spray), arsenic trioxide (applied as dry powder), sodium chlorate (liquid or dry), and boron compounds.

Spraying Equipment. Equipment for applying liquid materials for weed control varies greatly as to general appearance, yet fundamentally it all is similar. Sprayers consist of a pump and tank, a boom with flat fan-spray nozzles, and all mounted on some type of carriage for transporting. For non-corrosive materials, such as diesel oil and Sinox, any pump (rotary, displacement, or compressed air type) capable of maintaining 100 psi (pounds per square inch) pressure at the desired capacity, is satisfactory. Sulphuric acid requires either an acid-resistant pump and tank or use of the ejector type of sprayer. The use of acid also necessitates acid-resisting nozzles and boom.

Selective spraying on grain for control of broad-leafed annual weeds demands application during the season when the ground may be soft, hence provision must be made to transport heavy equipment without getting stuck and also to prevent cutting up the field any more than necessary. Many farmers have mounted their field sprayers on tracks which have proved very satisfactory. Tank capacities vary; for large sprayers from 500 to 1000-gal tanks are being used. Widths of spray booms likewise vary. From 20 to 30 ft has been common. On one or two large rigs 50 ft of boom has been used.

Construction and arrangement of booms are still matters of opinion. Some operators prefer all of the boom mounted off one side of the sprayer, others on both sides and at the rear of the sprayer, and still others on both sides and with a short middle section ahead of the tractor. Regardless of where the boom is mounted, it seems desirable to make it out of 1¼-in pipe, drilled and tapped for ¼-in male fitting nozzles. The boom must be adequately trussed to make it rigid. It should also be adjustable for height to adequately cover various heights of vegetation, and easily folded to permit passing through gates.

Nozzles should be the flat-fan type. Spacing will depend on the size of nozzles and quantity of material to be applied (Table 1).

Experiments with Sinox indicate that it can be applied in a fairly concentrated mixture, thus saving much transportation of water. This fact may also allow all of the spray equipment to be mounted on a tractor, thus simplifying the unit and reducing the cutting up of the field to a minimum. The airplane has also been used satisfactorily to spray Sinox on grain and flax fields. We may see an important development of this type of spraying in the future.

Application of Temporary Soil Sterilants. Carbon bisulphide is a clear, volatile liquid that vaporizes readily to give an extremely toxic gas which is heavier than air. When injected into the soil and sealed in to prevent its escape, it

A contribution of the A.S.A.E. Committee on Weed Control (1939-40). Author: Instructor and junior agricultural engineer, University of California.

TABLE 1. CALIBRATION TABLE FOR DELIVERY OF SPRAY AT VARIOUS SPEEDS AND VOLUMES

Volume, gals per acre	Speed, mph	Nozzles 1 ft apart 60-deg angle of spread: Required discharge per nozzle, gpm	Disk size, (drill number)	Pressure, psi	Nozzles 1.5 ft apart 80-deg angle of spread: Required discharge per nozzle, gpm	Disk size (drill number)	Pressure, psi	Nozzles 2 ft apart 90-deg angle of spread: Required discharge per nozzle, gpm	Disk size (drill number)	Pressure, psi
50	3.0	0.30	*	*	0.45	**	*	0.60	56	90
50	3.5	0.35	*	*	0.52	56	66	0.70	56	120
50	4.0	0.40	*	*	0.60	56	90	0.80	56	155
50	4.5	0.45	57	70	0.68	56	115	0.90	53	85
50	5.0	0.50	57	85	0.75	56	135	1.00	53	105
60	3.0	0.36	*	*	0.54	56	75	0.72	56	125
60	3.5	0.42	57	60	0.63	56	95	0.84	53	75
60	4.0	0.48	57	80	0.72	56	125	0.96	53	95
60	4.5	0.54	56	74	0.81	56	155	1.08	53	125
60	5.0	0.60	56	88	0.91	53	85	1.20	51	95
80	3.0	0.48	*	*	0.72	56	125	0.96	53	100
80	3.5	0.56	56	75	0.84	53	75	1.12	51	85
80	4.0	0.64	56	100	0.96	53	95	1.28	51	110
80	4.5	0.72	56	125	1.08	53	125	1.44	51	140
80	5.0	0.80	56	155	1.20	51	95	1.60	47	105
100	3.0	0.60	56	90	0.90	53	85	1.20	51	95
100	3.5	0.70	56	120	1.05	53	120	1.40	51	135
100	4.0	0.80	56	155	1.20	51	95	1.60	47	105
100	4.5	0.90	53	85	1.35	51	125	1.80	47	135
120	3.0	0.72	56	120	1.08	53	125	1.44	51	140
120	3.5	0.85	53	75	1.27	51	120	1.70	47	120
120	4.0	0.96	53	95	1.44	51	140	1.92	47	155

Pressure values are only approximate. Disks of different manufacture vary. Pressure should be adjusted to obtain necessary discharge.
*Too small for practical use.

kills all plant roots and fungi within the treated soil mass. This material has the advantage of leaving the soil within a few weeks' time, so that upon tillage and aeration of the soil, crops can again be grown.

The usual method of application of carbon bisulphide is by means of hand-probe injectors, of which there are several types. The liquid is applied in approximately 2 fluid ounce doses every 18 in and at a depth of about 6 in. While the hand method of application is somewhat slow, it is practicable for small areas. Since carbon bisulphide is expensive, its use is generally limited to small areas. Carbon bisulphide manufacturers have had power equipment for injecting CS_2 into soil for several years. During the past year the agricultural engineering division of the University of California was responsible for developing a positive pump metering device for the power applicator that has aided materially in securing uniform dosages[1].

Power equipment is relatively expensive and its use will, of course, be limited to contract operators rather than individual farmers.

Permanent Soil Sterilization Equipment. Spray equipment for this work may be used with a boom or hand guns, depending upon the kind of area being treated.

For distributing dry materials such as arsenic trioxide, sodium chlorate, or boron materials, some form of wheelbarrow type, hand-operated equipment is desirable. Equipment that is available commercially is limited to free flowing material such as sodium chlorate. For arsenic trioxide, which is a heavy material and packs badly, none of the commercial units are satisfactory.

A few years ago this division devised a wheelbarrow distributor that was capable of uniformly metering and distributing arsenic as well as mixtures of arsenic and chlorate or boron materials. Plans for this machine are available from our division. Another machine, a modification of the one just mentioned, was constructed by the U. S. Forest Service and was used to sterilize fire breaks in southern California.

Methods of chemical weed control are changing so rapidly that it is hard for anyone to specify the exact equipment that is required; hence, we cannot expect industry to have stock equipment available until we do settle the question. In the meantime we will have to adapt and custom build equipment to meet the needs of those desiring to use chemicals in the battle against weeds.

[1]French, O. C. Power equipment for injecting carbon bisulfide into soil. Agr. Engr. Vol. 20, No. 9 (September 1939).

Progress in Contour Furrowing

(Continued from page 484)

control purposes. These were justified under special conditions but do not appear to have a general application. The application of furrows to flatter slopes is receiving consideration in this section at the present time. It is hoped that the next year or two will develop some trends in the use of furrows under these conditions.

SUMMARY

The Committee has made no effort to draw any conclusions from the material submitted in this report. It has attempted only to pass on to interested individuals the progress being made in various sections of the United States in the application of pasture furrows to various conditions.

One condition has become very apparent to the Committee. This is that but few experiment stations have developed observations to the point that definite recommendations can be made. The Committee feels that more experimental work on this subject is desirable.

Electrical Weed Control

(Continued from page 486)

in diameter by 52 cm high. At the time of planting, tinned mill screen, 2x2-in mesh, was placed across the bulkans at 46, 31, and 16 cm from the top. When desired, these screens will be used as electrodes for future electrical treatments.

Growth of the morning-glory in the cardboard containers has not been as vigorous as expected. The rootstalks were planted in lengths of 15 cm, six to each bulkan, in September, and have been growing all winter in the greenhouse. They have made considerable root growth, but the top growth has not developed to a dense mat as was expected. Some of the bulkans were planted with clumps of morning-glory roots cut from an old morning-glory field with a cutter made from 8-in pipe. The morning-glory from these clumps has apparently made better growth than that planted with the pieces of morning-glory rootstalk.

Within the next few months it is planned to partially dry these morning-glory plants, and to give them electrical treatments of several kinds.

Engineering Problems in Grain Storage

(Continued from page 485)

cooling space, screened air inlets, an air resistance leg, and a variable discharge mechanism. Auxiliary equipment includes a fan, a hot water supply, and suitable power for driving the equipment.

A machine of this basic design can be built to any size and capacity desired. For the 1939 harvest a larger, portable unit was built, having a coil face area of 8.25 sq ft as compared to one square foot for the small machine used in most of the experimental work. Fig. 3 is one view of this machine, and shows the heat transfer coils, boiler, fan, and the gasoline engine unit, which furnishes power for the entire unit. By the use of loading elevator and bagger the labor required is reduced to a minimum. In this machine air vents, screen air inlets, and discharge mechanism are in multiple to eliminate funneling.

By varying the rate of discharge, the moisture reduction can be adjusted to the needs of the lot of grain. One lot of wheat was dried from 24.2 to 16.4 per cent moisture at 24 bu per hr. Another was dried from 18.5 to 14.0 per cent at 40 bu per hr. From 24 to 120 bushels per hour can be handled depending on the moisture reduction required.

FIG. 3 LARGE PORTABLE DRIER BUILT AT THE UNIVERSITY OF MARYLAND, SHOWING HEAT TRANSFER COILS, BOILER, FAN, AND GASOLINE ENGINE

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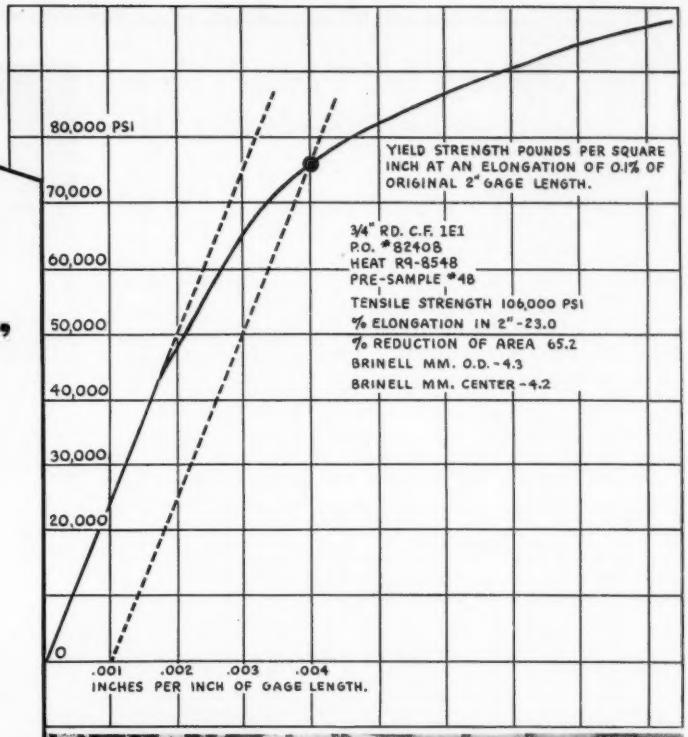

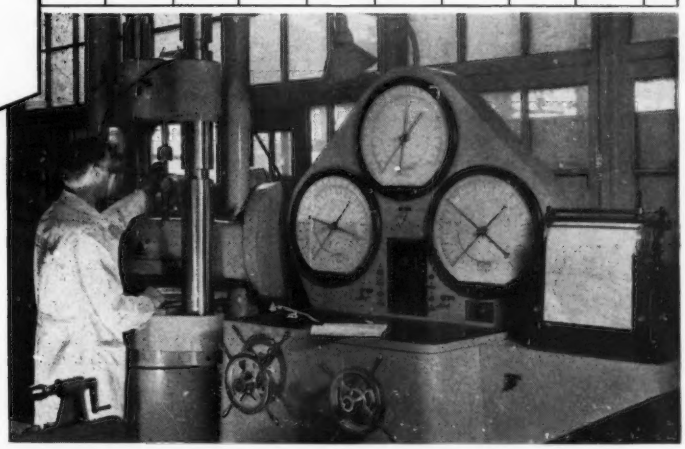

All metals stretch or compress under any applied loads. Quite aside from wear, the metal parts in any machine can be expected to remain useful only so long as applied loads do not deform them permanently. A shaft may "wind up" without taking a permanent twist, and withstand its load indefinitely. Likewise, so long as such a part as a spring deflects within its true elastic limit, it continues to perform successfully.

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Farm Drainage and Erosion Control in Highway Engineering

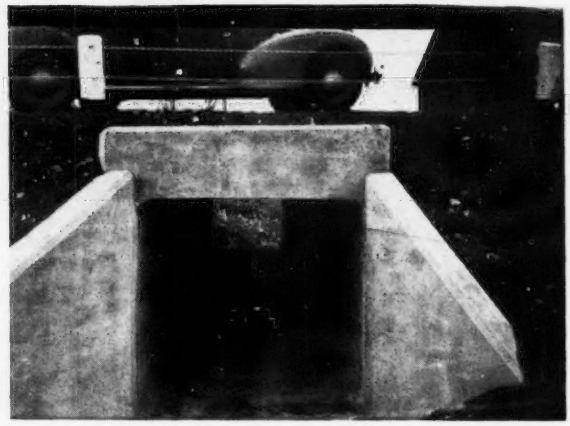
To the Editor:

YOUR very good editorial "Country Roads," in AGRICULTURAL ENGINEERING for September 1940, produced a different reaction on the writer than was intended. Instead of limiting ourselves to back roads and byways we should make the requirements of the farmer, as regards sufficient drainage outlet depth, felt with the various highway departments and railroads. Protection against erosion from their drains is also often necessary.

Many instances can be cited of organizations taking land by "right of eminent domain" with lack of consideration for the farmer who has had his farm cut up, but each drainage engineer has his own examples. Trouble sometimes results when the right of way divides landowners who do not agree on drainage outlets.

One highway maintenance crew installed a new culvert on a hillside to discharge road water out into a farmer's pasture where there was no sign of a watercourse. The road gutters on down the hill had been paved with cobbles for years and there had been no washing in them, but the farmer's land immediately started to gully. Wait's "Law of Operations Preliminary to Construction in Engineering and Architecture" states, "The defendant must not discharge an unnatural quantity of water upon the plaintiff's land. All the states hold the owner of land (in this case, the highway) liable to damages who collects water in a body and casts it upon the lower premises to their injury. The unlawful discharge of the water must have caused appreciable damages."

Culverts only deep enough to remove surface water are not sufficient. One outstanding example of cooperation was the du Pont Boulevard in Delaware. The chief engineer, Chas. M. Upham, asked the bottom elevation of a proposed large drainage ditch so they could place the foundations of a bridge deep enough to prevent undermining. The ditch, like many drainage improvements, was not constructed for a number of years, but the bridge was ready when it went through.



CULVERT UNDER MAIN HIGHWAY, DEEP ENOUGH TO PROVIDE DESIRED FARM DRAINAGE, LARGE ENOUGH FOR COWS TO WALK THROUGH, AND INSTALLED SO IT WILL NOT CONTRIBUTE TO SOIL EROSION

Relocations and new roads are often as hard on a farmer's field layout as a fire to a long line of breeding in a dairy herd. "Reasonable compensation" is like insurance, and does not pay for the time spent in forming the fields any more than insurance replaces the stock. A combination of a deep box culvert, large enough to serve as a cow underpass, has recently been noted and photographed. This is deep enough to serve as a good drainage outlet and obviates driving the herd across a heavily traveled highway.

Let us continue to urge that the farmer's interests be considered. He may be changed from an objector to a booster for a project. It is our duty to work for him.

JOHN R. HASWELL

Erosion Control with V-Shaped Ditches

ON our farm near Red Bay, Alabama, located in Itawamba County, Mississippi, we have been experimenting in conserving the soil and water on our land while growing field crops of various kinds.

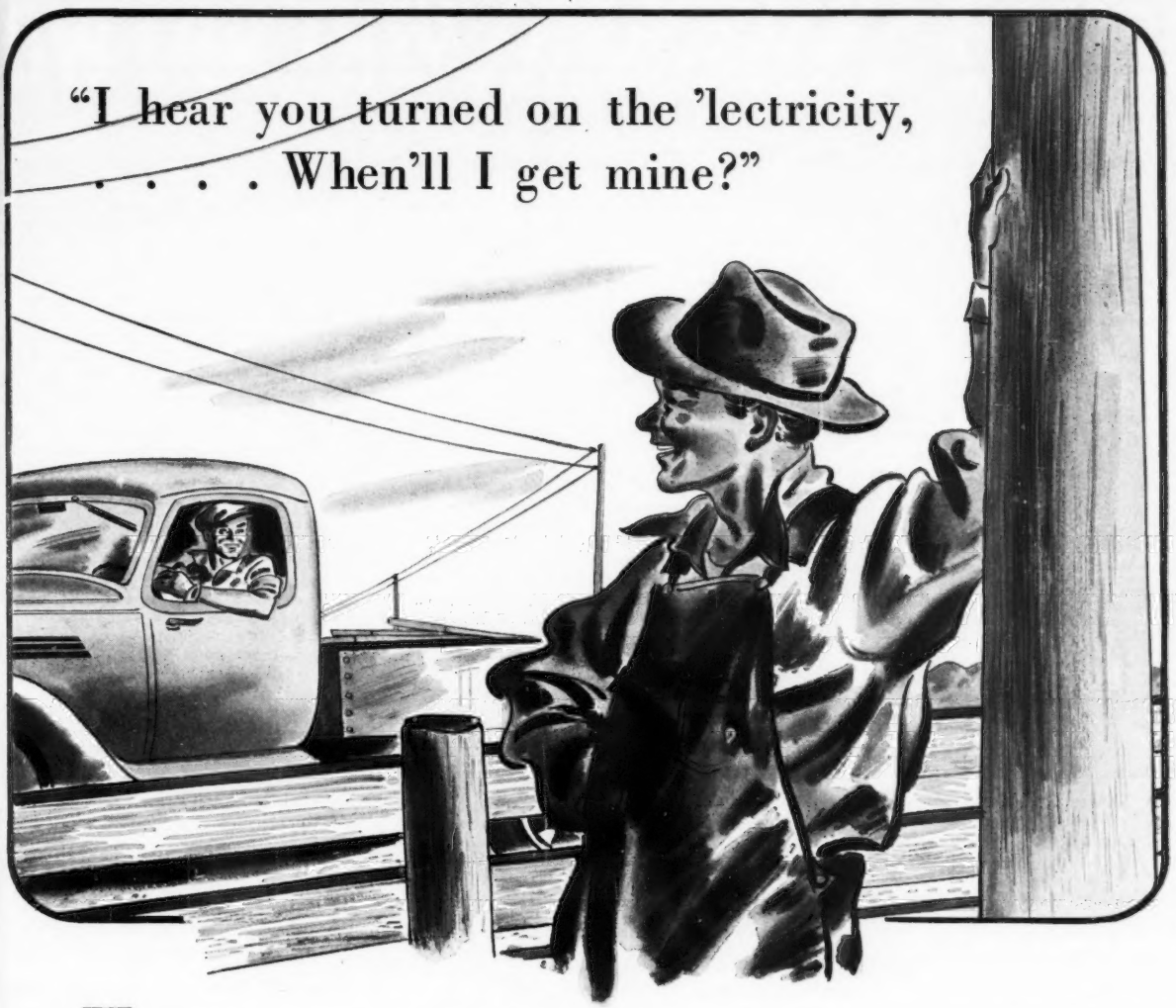
After several years' experimentation with terraces, made level, varying from 25 to 6 ft in width, we have abandoned terraces during the past two years and find that a level V-shaped ditch the width of a corn row, spaced like terraces, gives complete satisfaction. We balance all fields with these ditches, giving a vertical drop between them of not more than 4 ft on sandy land; and find that about 3 ft vertical drop is a good average on most rolling land.

To balance a whole field so as to give a uniform distribution of rainfall requires careful study, since all fields have varying slopes, depressions and mounds. Often these depressions can be best balanced with these level ditches by making the center at a right angle instead of giving a gradual circular curve. Mounds can be balanced with surrounding circular ditches having no outlets. These ditches are easily made by two rounds with a large turning plow and one furrow in the center with a middle-buster plow. We have kept each bank of these ditches bedded during the past two years. Finding that heavy rains do not break these beds and that the ditch will not overflow, we are making the ditches a little deeper, leaving the lower bank of the ditch level, and bedding only the upper ditch bank. This serves two purposes. The bedded bank prevents soil and water from filling the ditch during heavy rains. Having the lower ditch bank level, or sloped as the natural slope of the land below the ditch, will reduce sheet washing to a minimum. We are endeavoring to keep all water that falls in these ditches, to raise the water table near the surface, in order to tide growing crops during the dry seasons.

A long, level ditch is as easily maintained as a short, level ditch and there is no more soil erosion along the ditch or at the ends of the long ditch.

We have gathered data comparing the amounts of corn and cotton grown on these ditch banks with amounts grown on adjoining rows and find that the two rows on the ditch banks produced as much as three adjoining rows. On one test plat we made 204 bu of corn per acre this year and on another hill-land plat we gathered 105 bu per acre. Two rows of cotton 210 ft in length, produced 70 lb on the ditch banks, and two adjoining rows, 38 lb.—*From an article on "Intensive Agriculture," by John F. Davis.*

"I hear you turned on the 'lectricity, ... When'll I get mine?"



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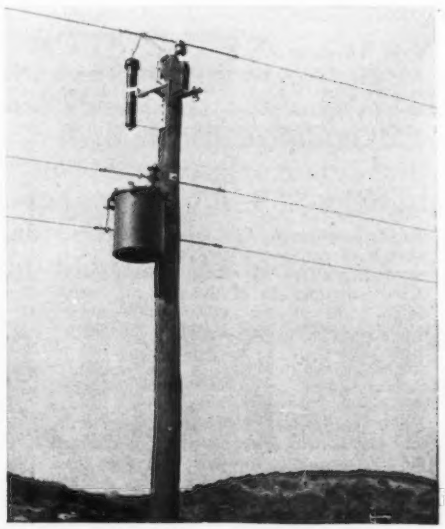

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NEWS

Light Fixture and Adapter Booklet

THE A.S.A.E. Committee on Farm Home Lighting has compiled a list of recommendations on "Electric Light Fixtures and Adapters for Farm Homes" which has recently been published by the Society as a 6x9-in bulletin of 16 pages.

Information given includes an outline drawing of each fixture or adapter, description, use for which recommended, number or size and wattage of lamps to be used, approximate retail price, and sources of supply. Recommendations include 18 fixture types, 7 portable lamps, and 29 adapters.

Members of the committee which prepared this compilation are Miss Ruby M. Loper (chairman), M. S. Blackwell, I. P. Blauser, J. P. Ditchman, Miss Myrtle Fahsbender, Miss Helen G. McKinlay, Miss Ellen Pennell, D. W. Teare, and, ex-officio, B. P. Hess and R. R. Parks.

Washington News Letter

FROM AMERICAN ENGINEERING COUNCIL

ELASTIC TAXES URGED TO STABILIZE ECONOMY

A SUGGESTION that extreme variations in the economic cycle might be dampened to some extent by raising tax rates during periods of prosperity and lowering them during depressions is contained in a report recently submitted to the Temporary National Economic Committee by experts of the Department of Commerce.

The suggestion is based upon a finding that the highest income class gets a larger share of the national income in prosperous times, while a drop in business activity finds this type of income rapidly diminishing. Higher taxes during the first, and lower rates for the second periods, would serve to retard or stimulate business and thus help to stabilize the national economy, it is argued.

RURAL POWER LINES SOUGHT

Requests for loans to build farm electric distribution systems total far more than the amount of money available, according to a recent report by the Rural Electrification Administration. As of October 12, 1940, $60,127,000 of the $100,000,000 made available by Congress on July 1 had been allotted, leaving a balance of less than $40,000,000 with which to meet applications totalling over $96,000,000 already received.

The report also stated that interest payments by systems already constructed during the first quarter of the fiscal year were 9 5 per cent larger than the amounts due, while repayments of principal were 17 per cent ahead of schedule.

DRAFTSMEN NOT EXEMPTED FROM WAGE-HOUR ACT

Revised definitions of executive, administrative, and professional personnel outside of the scope of the federal law regulating minimum wages and maximum hours of work do not include draftsmen "in the vast majority of instances," according to an explanatory letter written by Wage-Hour Administrator Fleming to the Seattle Association of Technical Engineers. Such workers are normally, Colonel Fleming points out, paid on an hourly basis and perform routine work; they do not therefore fall into the professional category. The revised definitions, touched on briefly in last month's BULLETIN, holds as follows:

Exemption as a professional worker is limited to those paid at least $200 per month who are engaged in work predominantly intellectual and varied in character, as distinct from routine work, requiring the consistent exercise of discretion and judgment, and of such character that the output or result cannot be standardized in relation to a given period of time, except that not over 20 per cent non-exempt work may be performed as an incident to employment without forfeiting exemption. In addition, the work must either require knowledge of an advanced type in a field of science or learning, as distinguished from a general academic education, or must be predominantly original or creative in a recognized field of artistic endeavor.

Exemption as an administrative employee is granted only to workers paid $200 per month or more engaged in non-manual work which requires the exercise of discretion and independent judgment whose duties fall within one of three categories: (1) regular and direct assistant to an executive or another exempt administrative employee; (2) office or field work, under only general supervision, directly related to management policy or business operations, along specialized or technical lines requiring special training, experience, or knowledge; (3) execution of special assignments or tasks directly related to management policies or general business operations.

Exemption as an executive is granted only to those meeting all of the following requirements: The employee's primary duty must be the management of the establishment, or a department or sub-division thereof; he must customarily direct the work of others; he must regularly exercise discretionary powers; must have the power to hire or fire and promote; must receive a salary of at least $30 per week; may perform no more than 20 per cent of his work in activities normally performed by non-exempt employees.

ST. LAWRENCE POWER STUDY STARTED AS DEFENSE MOVE

President Roosevelt has informed Congress that $1,000,000 from his "blank check" defense fund has been allocated to make preliminary investigations, including surveys and core borings, of the feasibility of constructing a dam on the International Rapids section of the St. Lawrence River for the development of hydro-electric power.

The allocation closely followed an agreement between the United States and Canadian governments authorizing such a study, and also the immediate diversion of an additional 5,000 second-feet of water from Niagara Falls for use to generate an additional 70,000 horsepower in existing power plants on the Canadian side of the Niagara River. The latter is contingent upon an immediate start of construction to divert water from the Ogoki River to Lake Superior.

Comprehensive development of the St. Lawrence River as an international waterway and source of low-cost power has been under consideration since 1907. A treaty authorizing this undertaking was defeated by the Senate in 1934, and a second proposal is now under negotiation between the two governments.

The President has also announced the appointment of a St. Lawrence advisory committee consisting of Chairman Leland Olds of the Federal Power Commission, chairman; Assistant Secretary of State A. A. Berle; Brigadier General Thomas M. Robbins, Corps of Engineers; and Gerald V. Cruise, representing the New York State Power Authority.

PEACE-TIME SPENDING RECORD EXCEEDED BY CONGRESS

During the third session of the 76th Congress, which convened in January 1940, and has not yet officially adjourned, appropriations and contract authorizations reached a grand total of $23,135,740,635.15, according to a tabulation by Chairman Taylor of the House Appropriations Committee. This figure does not include the total cost of the two-ocean Navy.

National defense expenditures accounted for over 56 per cent of the total, or $13,106,227,930.58. All other governmental functions financed from general revenues amounted to $6,982,084,801.28. The balance of the appropriations and authorizations are accounted for by payments of interest on the public debt and to various trust funds.

DEFENSE PROGRAM REACHES "TOOLING-UP" STAGE

With orders for material, equipment, and new plants to furnish the rapidly expanding Army and Navy still pouring out of Washington, the defense program as a whole has reached a stage where the production of necessary machine tools is the most important immediate bottleneck, according to William S. Knudsen of the National Advisory Defense Commission. Speaking before a group of Detroit automobile manufacturers, Mr. Knudsen stated that "the entire output of the machine tool industry for the next year is sold out right now" and warned that the big call for men and raw materials will not come until new aircraft, motor, tank, munition, and powder plants can acquire tools and get into production.

Nevertheless business volume, as measured by many signifi- *(Continued on page 494)*

A.S.A.E. Meetings Calendar

February 5-7, 1941—Southern Section Meeting, Atlanta, Ga.

February 7-8, 1941—Pacific Coast Section Meeting, Phoenix and Tucson, Ariz.

June 23-26, 1941—Annual Meeting, Knoxville, Tenn.

HOW CAN THEY *IMPROVE* LUMBER?

In the development of Agricultural America, lumber played a dominant role as it was the most economical material for farm construction. It was easy to work — easy to keep up. Buildings made of good lumber could be economically remodeled to suit new needs.

Today, 4-Square lumber plays an even more important role in producing farm profits because it has received the benefits of better designing, and of improved manufacture.

Now engineers have available in 4-Square lumber a better building material. 4-Square lumber is made in a wide variety of species and grades to fit every structural need. It is properly seasoned. It comes in standard lengths and sizes, already squared at ends and edges. These basic improvements enable the engineer to design for economical erection and less waste of material. 4-Square ready-to-use lumber helps the designer to promote better workmanship and obtain more durable construction.

Correctly designed farm buildings properly built of good lumber give more years of service — plus the added value of economical remodeling to suit new needs. Available is the 4-Square Catalog of Lumber Products.

4-SQUARE LUMBER

WEYERHAEUSER SALES COMPANY • ST. PAUL, MINNESOTA

4-SQUARE GUIDE-LINE FRAMING

4-Square Guide-Line Framing has scored lines lightly and squarely pressed in across the face of each piece every inch of the length. Numerals are marked every foot to aid in the proper alignment of all parts of the framework. The carefully squared ends of each piece are trade-marked: "4-Square Guide-Line Framing". The edges at both ends of every piece are further marked with the grade and species, together with "Guaranteed by Weyerhaeuser". Made only of Douglas Fir, Guide-Line Framing is available in exact even lengths from 8 to 20 feet.

Personals

Hobart Beresford is author of "Farm Electrification in Idaho," published as Idaho Agricultural Experiment Station Bulletin No. 237. It is in 8½x11-in page size and includes a number of pictures, graphs, maps, and tables showing farm applications and the trend, extent, distribution, and organization of rural electrification in the state.

Everett H. Davis has received an appointment as utilization representative with the Rural Electrification Administration in the Pacific Northwest area with headquarters at Spokane, Wash. He was formerly extension agricultural engineer at the Oregon State College.

Clyde H. Emmons has been appointed junior construction engineer by the Farm Security Administration and will be engaged in supervising construction of irrigation structures and drainage work. His headquarters are at Wichita Falls, Texas.

William E. McCune has been appointed graduate assistant in the agricultural engineering department at the A. & M. College of Texas. College Station. He was previously with the J. I. Case Co.

Earle K. Rambo and *G. E. Martin* explain "Mower Repairs and Adjustments" in Tennessee Agricultural Extension Publication No. 240.

Frank J. Reynolds, manager of the agricultural extension department, American Steel and Wire Co., has moved his headquarters from Cleveland to the Pittsburgh offices of the company.

Samuel Strebin was recently transferred from the Soil Conservation Service to the Grazing Service of the U. S. Department of the Interior with headquarters at Salt Lake City, Utah. His new position will be that of range examiner.

H. B. Wall has received an appointment in the grade of Junior agricultural engineer with the U. S. Soil Conservation Service, and is located at Hammon, Okla. Until his appointment, he was a trainee with the Goodyear Tire and Rubber Co.

F. D. Yung is the agricultural engineering contributor to Nebraska Agricultural Experiment Station Circular 65, on "Cooling, Storage, and Transportation of Milk and Cream." It gives particular emphasis to simple equipment and methods for cooling milk and cream in cans.

Applicants for Membership

The following is a list of applicants for membership in the American Society of Agricultural Engineers received since the publication of the November issue of AGRICULTURAL ENGINEERING. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

H. L. M. King, ground instructor in aero engines, Regina Elementary Flying School, Regina, Sask., Canada. (Mail) 2320 Angus Street.

Clarence T. Rasmussen, chief engineer, experimental department, John Deere Wagon Works, Moline, Ill.

Stanley D. Russell, designing engineer, J. I. Case Co., Racine, Wis.

Gustavus H. Stewart, rural electrification specialist, South Carolina Extension Service, Clemson, S. C.

Student Branch News

OREGON

By Bill Etter

OREGON'S Student Branch of the A.S.A.E. is turning all of its efforts toward earning money for a trip to Tennessee next summer for the annual meeting of the A.S.A.E.

The group is doing all the farm work possible with its three tractors loaned by implement companies of Portland. It also has a heavy-duty implement trailer to aid in the movement of the machinery.

The Branch members, lead by Clyde Walker, associate professor of agricultural engineering, traveled to Newberg, Oregon, October 21, to witness the finals of the National Farm Youth Foundation tractor operating contest.

Bill Griebler, president of the club, Larry Swarner and John Bursik, Branch members, and W. J. Gilmore, professor, attended the Industry Seminar and all reported having a good time.

Many of the members have stated that they intend to let Tennessee know that Oregon still exists, at the A.S.A.E. meeting in 1941, so the club motto is "Tennessee for '41".

MISSOURI

MEETINGS are being held semi-monthly, five of which have been held to date. Programs consist of talks by student members and educational motion pictures. Membership at present consists of fifteen.

A get-acquainted picnic was held in October with thirty-two faculty, guests, and student members present. Plans were made to serve refreshments during Farm and Home Week but due to weather conditions these plans failed to materialize. A dance for the members and their guests was held in November with twenty-four faculty, guests, and student members present.

Other planned activities are as follows: The publication of our student branch annual—"AG ENGINEER," an exhibit at St. Pat's Week and also an exhibit at Farmer's Fair. Plans are being made to compete for the F.E.I. cup award.

Social activities planned include a dance and a picnic to be held in the spring. A banquet for members is to be held late in the spring.

TEXAS

THE A.S.A.E. Student Branch of Texas A. & M. College held its first meeting shortly after the beginning of the fall semester. Plans were discussed for the coming year and short talks were made by members of the faculty. It was reported at the meeting that 132 students are enrolled in agricultural engineering. There are 34 seniors, 35 juniors, 19 sophomores, 40 freshmen, and 4 graduate students.

The second meeting of the year was given over to the annual picnic with a short business meeting at the close.

Seniors, accompanied by two members of the faculty, made their annual inspection trip to the state fair at Dallas and to the Mesquite Soil Conservation Project, October 16 and 17. The 32 members of the party traveled by a special bus chartered by the Student Branch. The purpose of this trip was to inspect the new developments in farm equipment and to observe some of the soil conservation practices being carried on in the state. The first day was spent on the fair grounds at the exhibits of the different implement companies. A great deal of equipment was seen in operation. There were also many machines shown in section and some machines had transparent observation plates so that the mechanism could be observed while in operation.

One of the equipment companies was sponsoring a daily radio program originating at the fair, and on that day the A. and M. boys were given a prominent place on their program. Several school yells were given and one of the boys demonstrated his skill on the violin.

On the following morning one of the implement branch houses was visited and also the wholesale distributing plant of one of the large grocery companies.

The last part of the trip was spent on the Mesquite Soil Conservation Project. The group was taken over the project area, various field practices were explained, and the instruments shown that are used in the research work carried on in connection with this project.

At both the fair and at the Soil Conservation Project the members of the group were shown around by some of the former graduates of the department who are now holding positions with farm equipment companies and with the U. S. Soil Conservation Service.

Washington News Letter

(Continued from page 492)

cant indices, is unmistakably on the up grade. Heavy buying in steel, textiles, and many other markets is attributed less to actual defense orders than to the accumulation of stocks by other manufacturers apprehensive of future shortages.

During the last week in October steel mills were operating 95.7 per cent of capacity, with many units operating three 8-hr shifts on a 7-day week. Domestic consumption of chemicals for the first nine months of 1940 increased almost 20 per cent over the same part of 1939, while exports rose more than 50 per cent. Predictions for the final quarter of this year indicate an all-time high in production volume for this industry. Private engineering construction awards for the last week in October were the largest of any week for the past 10 years, more than double the figure for the preceding week and four times as much as for the corresponding one in 1939.

Despite the closing off of a large part of Europe to American products, the Department of Commerce reports a 37 per cent increase in exports for the year ending in September, 1940, as compared with the preceding 12 months. Specific items include a 56 per cent increase to the United Kingdom, 50 per cent to Canada, 80 per cent to India, 67 per cent to Brazil, and 80 per cent to both Argentina and Chile.

To make sure that the needs of national defense do not suffer from the competition of private orders and purchases from abroad, President Roosevelt by executive order has set up within the Defense Commission a priorities board with full power, when necessary, to determine the order in which deliveries shall be made.

HIGH COMPRESSION TRACTOR SALES ZOOM!

Increasing demand for up-to-date, economical power seen

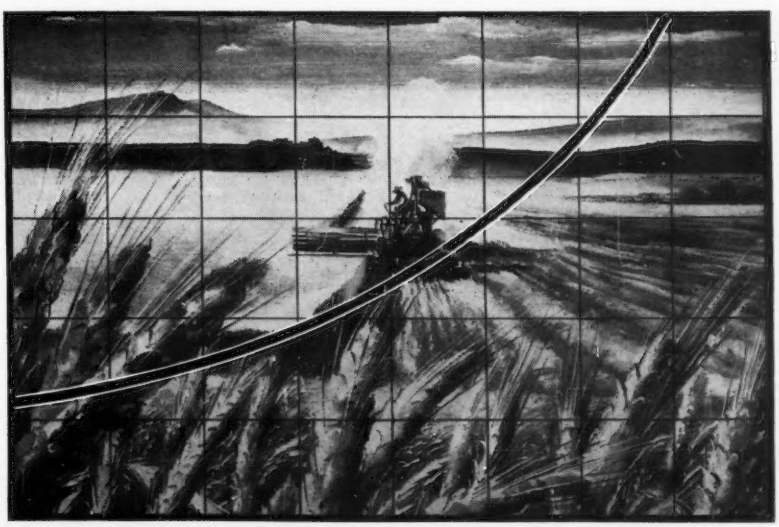
Since the introduction of the high compression tractor five years ago, sales have climbed so rapidly that today a number of leading manufacturers report that 85% of their total sales are of this modern type.

The demand for light, powerful tractors is so great that practically all models offered by the leading tractor manufacturers have high compression engines as either standard or optional equipment. Manufacturers report that in many of their branches 100% of current sales are high compression or gasoline models! And the farm market studies of oil companies show that a rapidly increasing number of tractor owners are changing over old low compression engines to high compression engines in order to take advantage of the greater power and economy of good *regular* gasoline.

Back of this powerful trend toward high compression tractors on farms of all sizes is this fact: the less farmers have to pay for power to do their plowing, cultivating, harvesting and other farm work, the more tractors they'll buy. And more and more of them are realizing that the high compression tractor operating on good regular gasoline puts convenient, flexible power within their reach—makes it possible for them to get a real *bargain in horsepower.*

Why not cash in on this *fast-moving trend* to high compression? Remember, lower cost per horsepower is a powerful argument when it comes to selling tractors.

Ethyl Gasoline Corporation, Chrysler Building, New York, N. Y., manufacturer of anti-knock fluids used by oil companies to improve gasoline.



SELL MORE HORSEPOWER AT LESS COST THROUGH HIGH COMPRESSION

Agricultural Engineering Digest

A review of current literature by R. W. TRULLINGER, assistant chief, Office of Experiment Stations, U. S. Department of Agriculture. Copies of publications reviewed may be procured only from the publishers at the addresses indicated.

POULTRY EQUIPMENT, *H. H. Alp.* (Coop. U.S.D.A.) Illinois Sta. (Urbana) Cir. 506 (1940), pp. 20, figs. 32. Suggestions for the construction of the following devices are accompanied by dimensioned drawings: Simple chick feeders, indoor hen feeders, weatherproof range feeder, open nests, and roosts and droppings board or pit. Other equipment, discussed and shown in photographs or in drawings without dimensional detail, comprises chick roosts and brooder, outdoor wire pens, movable roosting shelters, shade shelters, catching crate, egg storage cellars, trap nests, range watering device, range watering system, heater for water trough, electric water heater, broody coop, and screen platform. The circular deals with models and types of equipment that are simple to construct and have proved their worth in everyday use on poultry farms in Illinois. This is a revision of extension Circular 333.

A LAMP-TYPE ELECTRIC PIG BROODER, *F. E. Price, A. W. Oliver, and I. Branton.* Oregon Sta. (Corvallis) Cir. 135 (1940), pp. 4, figs. 4. The device described is made in the form of a right-angled triangle to fit into a corner of the pen, the two short sides being 3 ft in length. The framework is of 2x4-in material and is supported by three 12-in legs of the same, placed in the angles. The top, or hover, is of 0.25-in or 0.5-in plywood and has a centrally placed circular opening, 12 in in diameter, over which is set a sheet-metal reflector cone carrying a rubber-covered socket and a 100 or 150-watt electric light bulb. The use of rubber-covered shop extension cord is considered necessary to safety. The reflector opening is to be framed, on the under side of the hover, with 2x2-in pieces, and a protective covering of 0.5-in mesh hardware cloth is to be attached to this frame. The top of the brooder is to be protected by two 2x12-in planks set one above the other to form a 2-ft wall resting on the long side of the triangle and attached to the side walls of the pen.

The use of this equipment reduced losses during cold weather.

DEHYDRATED AND SUN-CURED HAY, *S. I. Bechdel, A. W. Clyde, C. O. Cromer, and P. S. Williams.* Pennsylvania Sta. (State College) Bul. 396 (1940), pp. [2]+24, figs. 8. For artificial drying of hay, both rotary drums and conveyor machines were tested. To accelerate field drying, experimental crushers, cracking stems by passing the freshly cut hay between rolls, were tried with encouraging results. The bulletin also reports results of feeding experiments showing the superiority of artificially dehydrated hays over field-cured or silage products.

The drum drier used feeds the chopped hay material into a current of hot gases and heated air drawn from the furnace into the innermost of three concentric drums, to pass backward between the innermost and the second drum and forward again between the second and outer drum to the outlet of the exhaust fan. This machine evaporated, at its rated capacity, 1 ton of water per hour, producing ⅜ ton of dried hay (about 12 per cent moisture content) from freshly cut alfalfa of 75 per cent moisture content or ¾ ton from partially dried material of 60 per cent moisture content. The exhaust fan could be operated successfully at somewhat less than 1,100 rpm, instead of the recommended speed of 1,350 rpm, with a decrease in exhaust-heat loss and in exhaust-fan power consumption. Fairly complete data from a 7½-hr run are tabulated. The conveyor drier, of the countercurrent type, passes the furnace gases first through a long tunnel under the drier and through a screen to prevent sparks from reaching the hay, and then back against the motion of the conveyor, baffles causing the gases to pass alternately upward and downward through the mat of hay. The freshly cut material for this drier is chopped to 1½ in and distributed in a layer of uniform thickness by a mat-forming device. The thermal efficiencies of the conveyor machines were 63 per cent for the smaller and 65 per cent for the larger, as against 67 per cent found for the concentric drum type.

It is believed that the cost of dehydration, including all overhead, will vary between $5 and $10 per ton. Fuel oil can be burned with better efficiency and automatic control, but the local coal production makes coal usually the cheaper fuel in Pennsylvania. Large initial investment, lack of small movable driers compelling cooperative ownership, and the necessary haulage of green forage and hay render the total cost too high to permit dehydrated hay to compete with sun-cured hay in dairy feeding. Dehydrated alfalfa, however, at a cost much higher than sun-cured alfalfa, is much in demand for poultry rations. The supply of dehydrated alfalfa has never exceeded the demand in this country.

The experimental crusher described passes the cut forage material between rolls, cracking the stems lengthwise with very little effect on leaves, and drops the crushed hay to the ground for natural drying. Hay so treated dried enough for storage in about 1 day less than the usual curing time. The crushed hay dried no faster in the artificial driers than the untreated material, but the crushing treatment is considered to have some advantage when partial field drying is to precede artificial dehydration. Crushing soybean hay reduced the field drying time from 17 to 5 days and resulted in a better product. It is expected that a practical crusher will be on the market soon.

THE EFFECT OF SEVERAL CHEMICALS ON THE SWELLING AND THE CRUSHING STRENGTH OF WOOD, *H. D. Erickson and L. W. Rees.* (Minn. Expt. Sta.) Jour. Agr. Res. [U. S.] 60 (1940), No. 9, pp. 593-603, figs. 2. The degree of swelling of test blocks of *Pinus resinosa* (red pine) produced by concentrated solutions of certain inorganic salts, and of chloral hydrate, tannic acid, urea, pyrogallol, and resorcinol, as well as by certain of the lower aliphatic alcohols, ethylene glycol, and acetone, were determined, together with the effect of these reagents upon the maximum crushing strength of the wood. In the test with each liquid, 10 blocks, approximately 1x1x2 in when green, were used. The blocks were dried slowly to a uniform 2 per cent moisture content before treatment. Adequate penetration was obtained by forced submergence and intermittent application of a high vacuum, except that high vapor pressure of the liquid prevented attaining a high vacuum over some of the organic liquids. In the strength test a uniform rate of compression strain, approximately 0.035 in per minute was used.

An inverse relationship between maximum crushing strength and swelling caused by the organic liquids was indicated. At the same degree of swelling, the organic liquids swelled and weakened the wood less than water did. Swelling and loss of strength decreased with increasing carbon number of the alcohols. Benzene had no appreciable effect on wood. Nearly complete swelling of wood in *n*-butyl alcohol required 120 days. The solutions of potassium sulfate and of lithium, sodium, potassium, magnesium, calcium, and manganese chlorides increased the crushing strength as compared with that of water-treated wood. Potassium bromide very slightly increased the strength. Potassium thiocyanate and potassium iodide distinctly decreased the strength. In the organic group, urea, resorcinol, and pyrogallol, which caused a relatively high degree of swelling, markedly decreased the crushing strength, whereas chloral hydrate, which also swelled the wood strongly, and tannic acid, which caused little swelling, increased the strength decidedly.

INFLUENCES OF VEGETATION AND WATERSHED TREATMENTS ON RUNOFF, SILTING, AND STREAM FLOW. A PROGRESS REPORT OF RESEARCH. U. S. Dept. Agr. Misc. Pub. 397 (1940), pp. 80, figs. 26. An introductory section on soil, vegetation, and water flow describes the hydrologic cycle and related phenomena. The investigational data are detailed under the further heads—factors affecting infiltration, influences of vegetation on water behavior, consequences of change in vegetal cover, runoff and erosion control by cropping practices and mechanical measures, and current research in water conservation, with numerous subtopics.

AGRICULTURAL ENGINEERING INVESTIGATIONS AT THE ARIZONA STATION, Arizona Sta. Rpt. 1939. pp. 42-45. This report notes ground-water studies in the Cortaro-Marana district, the Eloy pumping district, the upper Santa Cruz Valley, the Queen Creek ground-water basin, and the Little Chino Valley, and work indicating that snow-survey forecasting, though valuable in states further north, has not shown much promise in 2 years' work in Arizona (coop. U.S.D.A. et al). *(Continued on page 498)*

"THAT'S THE SWEETEST TRACTOR I EVER HANDLED"

"WHAT DO THEY DO TO MAKE THEM RUN SO SMOOTH?"

WELL, for one thing, in addition to progressive designing and precision workmanship, leading manufacturers are using more and more U·S·S Carilloy Alloy Steels in farm equipment.

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Because they give the farmer the *dependability* that in his mind outweighs every other feature, they make farm equipment not only more profitable to use but safer to recommend and easier to sell.

That's why you'll find U·S·S Carilloy Alloy Steels in the finest agricultural equipment made in America. These made-to-measure steels are produced by specialists who make fine alloy steels only — and whose aim is to give you the exact grade of steel that will do the best job in your product—at lowest cost. We welcome the opportunity to prove the economic advantages of U·S·S Carilloy Alloy Steels as applied to your designs.

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Attractive concrete milking barn and bottling plant of Meadowlark Dairy, Pleasanton, Alameda County, Calif.

Build *for* Thrift and Smart Appearance with CONCRETE

Beauty won't keep the rain out. But more beauty in farm buildings is certainly a laudable objective. And your farmer client appreciates better appearance—especially when combined with a thrifty, permanent building material.

Attractive wall effects are easily obtained at moderate cost with reinforced concrete or concrete masonry. A wide choice of surface textures and colors is available. And concrete doesn't require periodical protective painting. It *keeps* its good appearance with very little upkeep.

Help farmers get the pleasing appearance they want by designing farm structures with good-looking, economical, firesafe concrete.

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A national organization to improve and extend the uses of concrete . . . through scientific research and engineering field work

Agricultural Engineering Digest

(Continued from page 496)

COTTON-TILLAGE STUDIES ON RED BAY SANDY LOAM, *J. W. Randolph, I. F. Reed, and E. D. Gordon.* (Coop. Ala. and Miss. Expt. Stas.) U. S. Dept. Agr. Cir. 540 (1940), pp. 55, figs. 34. Seedbed preparation experiments, planter tests, cultivation experiments, and a study of the relation between apparent specific gravity and crop yield are separately dealt with.

With respect to seedbed preparation, the desirable physical condition at planting time for Red Bay sandy loam was found to be that of a relatively low apparent specific gravity with about one-third of the top 8 in of soil in soft clods embedded in settled, finely granulated soil. The structure should be such that the soil will not settle to a high apparent specific gravity by fall. With seed, fertilizer, and methods of planting and cultivation kept constant, the 6-yr average yields varied, due to seedbed preparation methods, from 1,038 to 1,324 lb of seed cotton per acre. Plats receiving no seedbed preparation produced an average of 1,100 lb per acre.

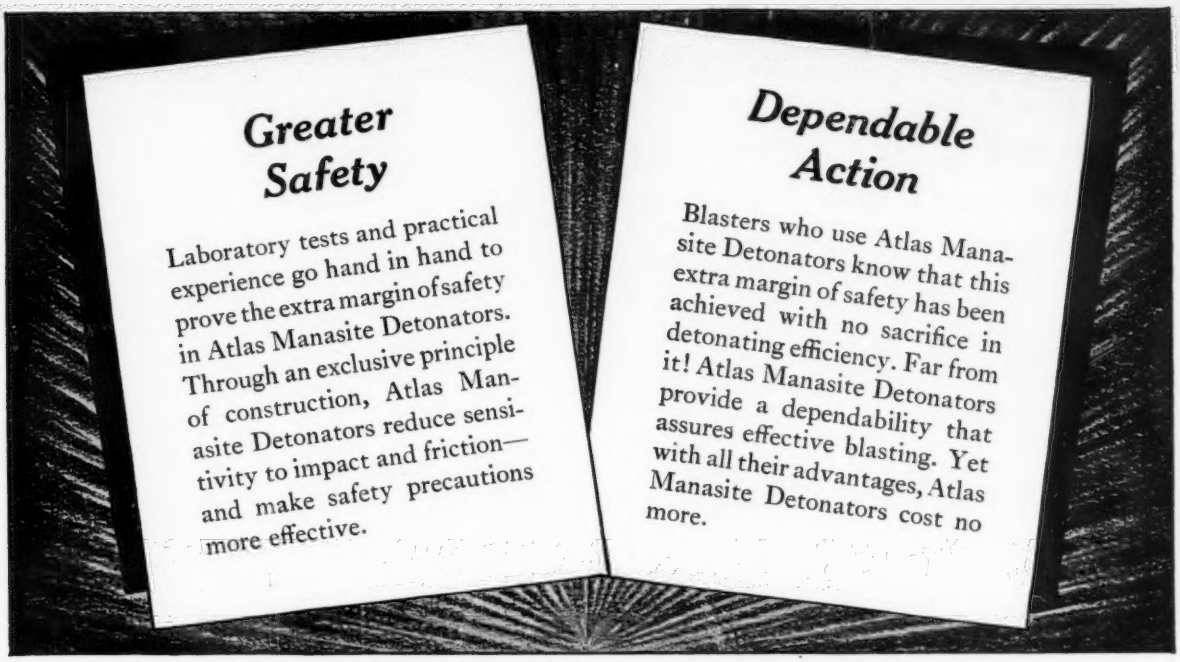
Preparation of the seedbed by plowing or breaking the row and then the middle in winter not only produced the best yields but released labor in the spring for handling feed and food crops. Excessive tillage in seedbed preparation did not increase the yield per acre much above that obtained when there was no seedbed preparation. A loose, overpulverized, structureless condition was produced in the surface soil, which consolidated rapidly after the normal spring rains. These operations tended also to pack the subsoil, producing an impervious layer which prevented development of a normal root system, slowed up drainage, and increased erosion. Maximum yields per acre and returns per man were obtained by use of a few properly executed, well-timed operations. The tillage work under the row was found to be more beneficial than work done in the middles if the soil is not overpulverized. Yield increased with the depth of work under the row down to 8 in. Subsoiling did not increase the yields. Deep plowing gave the best control of weeds. Shallow working or ridging the soil did not cover weed seed deep enough to prevent their germination. Tillage methods that increased the moisture-holding capacity of the soil tended to increase yields.

The planter tests showed that the machine must have weight, strength, and contact with the ground sufficient to hold the opener to the desired depths in the soil, and that a sweep mounted on the front of the planter to cut the bed to the desired height improved the yield of seed cotton, removed weeds and trash from the row, and made possible a better first cultivation. The variable-depth method of planting practically insured a stand of cotton on the first planting even under the unfavorable conditions often encountered in early spring, giving better stands where soil crusts formed than did planting at constant depth, because conditions favorable for development of crusts caused seed planted shallow to germinate and emerge before the crust was fully formed. The seed press wheel helped to insure a quick stand, but tended to reduce yields. It is not recommended for the conditions encountered in this experiment. A surface press wheel should be used throughout the season. The open-type wheel gave best results when the soil was inclined to crust, but the closed or solid-tire type was best under certain dry conditions. The covering spoons or disks should be arranged to throw a uniform amount of soil onto the row.

The cultivation experiments showed that cultivation should be shallow and only frequent enough to control weeds. Cross-row cultivation with drag harrow, spring-tooth weeder, or rotary hoe controlled the weeds, removed weak plants, and lengthened the chopping period, allowing hoe hands to select the better plants to leave for stand. Cross-row cultivation can be done economically as the equipment used handles a relatively wide strip and has light draft. It may be destructive to cotton planted on very loose beds or in a furrow. The same three tools were found very effective for breaking soil crusts to allow cotton seedlings to come up. The rotary hoe seemed most satisfactory. Cross-row cultivation before and during chopping time followed by enough shallow-row cultivations to keep down the weeds produced the maximum yield of seed cotton and was efficient in the use of labor.

Apparent specific gravity, measured by drying and weighing fixed portions of a core sample taken with a thin-walled steel tube and determining the required figure from the weight per unit volume, showed that the type, number, and time of the seedbed-preparation operations substantially altered the compactness at certain depths. The data indicate close correlation between yield and apparent specific gravity for certain ranges of depth in the row area, especially between 4 and 8 in in the top 2 in, because of cultivation. The average apparent specific gravity of the soil in the cotton row was found to be less after harvest than in the period immediately following planting. This loosening is attributed in part to the permeation by roots and in part to the alternate wetting and drying of the soil through the growing season.

(Continued on page 500)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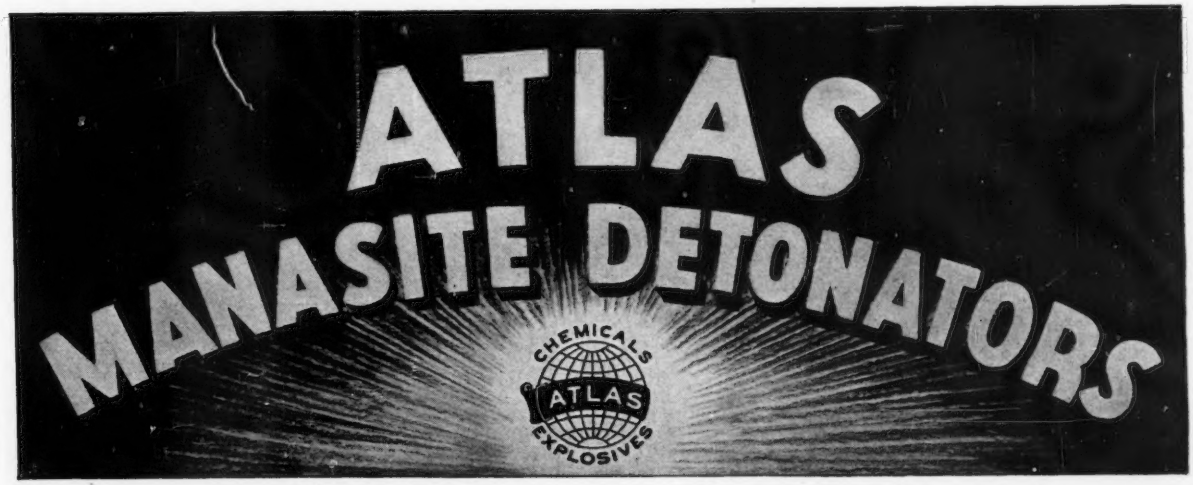

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(Continued from page 498)

STOCK-WATER DEVELOPMENTS: WELLS, SPRINGS, AND PONDS, *C. L. Hamilton and H. G. Jepson.* U. S. Dept. Agr., Farmers' Bul. 1859 (1940), pp. II+70, figs. 44. It is pointed out that although it is quite commonly believed that improved livestock-watering facilities are required only in range areas in the arid and semiarid states, many sections of the more humid states have inadequate watering facilities on farm pastures. Recent periods of drought have revealed these deficiencies. Pasture water supplies that may be well located and have served satisfactorily for several years often go dry during or immediately following repeated dry periods. The development of necessary pasture and range watering facilities aids indirectly in the establishment of beneficial soil and water conservation practices in both range and agricultural areas. With proper development and distribution of water supplies, grazing can be restricted on overgrazed, eroded, or depleted range land and the livestock systematically rotated over other areas according to their grazing capacity. In farming areas adequate water supplies in pastures will encourage more uniform grazing, facilitate pasture-improvement practices, and retard erosion damage. They may also enable profitable utilization for pasture of soil-conserving crops and of erodible or steep areas unfit for producing cultivated crops.

This bulletin takes up, among other topics, planning stock-water developments, wells, troughs and tanks, springs, reservoir inflow, excavated reservoirs, impounding reservoirs, and protection and maintenance. The impounding dams dealt with are of the earth-fill type for small reservoirs. Natural and artificially made vegetated spillways and mechanical spillways for such reservoirs are also described and illustrated.

EXPERIMENTS WITH ELECTRIC WATER HEATERS FOR DAIRY FARMS, *J. M. Fore* and *T. E. Hienton.* Indiana Sta. (Lafayette) Bul. 447 (1939), pp. 12, figs. 11. The efficiencies of 15 heaters, 11 of the tank type and 4 portable immersion units, were tested under various conditions in the heating of water for cleansing dairy utensils. The average final temperature attained was 174.9 F, as against from 165 to 170 F, considered necessary for proper washing. The most important single efficiency factor was that of the insulation, the tank heaters showing an average efficiency of 77.7 per cent, as compared with the 62.8 per cent average efficiency of immersion heaters operated in uninsulated pails. Of the immersion heaters, 2 used in uncovered, uninsulated pails showed an average efficiency of 77.85 per cent. The same 2 heaters in pails placed in heat-insulating materials in a box and provided with an insulated cover operated at an average efficiency of 88.5 per cent. Immersion heaters used in uninsulated water containers were more efficient when of 1 kw or greater wattage.

Electric water heaters of from 3 to 15-gal capacity are practical for use on Indiana dairy farms producing bulk milk, where electric service is available. Five of the tank-type heaters, equipped with heating elements of 2,000 watts or more, heated 5 gal of water from tap temperature to 170 F in less than 1 hr. Three immersion heaters and 1 small tank heater heated 3 gal of water to the same temperature in less than 1 hr. Such heaters may be connected before milking is started to provide from 3 to 5 gal of hot water when milking is finished. Of the tank heaters of low wattage (from 250 to 1,000), 3 equipped with thermostats required more than 1 hr to heat water to 170 F. These heaters, because of the thermostat control, are operated continuously. They will supply from 8 to 15 gal of hot water when needed.

AGRICULTURAL ENGINEERING INVESTIGATIONS AT THE INDIANA STATION, Indiana Sta. (Lafayette) Rpt. 1939, pp. 12, 13, 34-38, 39-41, 42-45, 72, 77, 78, 91, 92, figs. 5. This report notes work on electric pig brooders, and a study of the use and practicability of electric heat for warming drinking water for livestock, both by T. E. Hienton and J. M. Fore; mechanical refrigeration of eggs, by Hienton, Fore, and E. R. Menefee; use of electric energy in brooding, and electric dairy water heaters (above noted), both by Hienton and Fore; precooling of fresh fruits in refrigerator cars, by Hienton and K. I. Fawcett; electric soil sterilization, by Hienton and J. B. Greiner; codling moth control with electric traps, by G. E. Marshall and Hienton; refrigeration for the farm household and for farm produce, by G. Redfield and Hienton; use of electric traps as a possible control for European corn borer and other field-crops insects, by Hienton and G. A. Ficht; plow trash shields, by R. H. Wileman; Canada thistle and similar weed-control implements, by Wileman and O. C. Lee; low corn-cutting demonstrations, and rubber tires for tractors and farm implements, both by Wileman; seed-corn drying, by Wileman and A. J. Ullstrup; poultry-house ventilation, by I. D. Mayer and C. W. Carrick; and combined harvester thresher, atmospheric corrosion of wire and wire products, experimental dairy barn, hay storage, field ensilage harvester, practical hog houses for Indiana, and power-driven manure spreader, all by Mayer.

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Results of Investigations of Milk Cooling Costs and Effectiveness *Roberts and Larson*

The Electric Ultramicrometer Circuit as a Drawbar Dynamometer *G. W. Giles*

Research Work in Wheat Storage Under Farm Conditions *C. F. Kelly*

Runoff Data from Small Agricultural Watersheds *D. W. Cardwell*

Possibilities of Electrical Weed Control by Root Killing *E. M. Dieffenbach*

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This new "S" series, including also an orchard model "SO" and four-wheeler "S", embodies a brand-new engine created by Case engineers and built by Case workmen. To the "lugging" character of torque curve and the durability of construction for which Case engines have long been known, it brings still greater flexibility, still wider speed range of smooth, full-torque operation under close governor control. A fourth gear forward permits fast transport without compromising capacity or efficiency in any of the three carefully stepped field speeds. More extensive use of anti-friction bearings makes Synchronized Steering easier than ever, and provision for perpetual take-up makes possible permanent freedom from backlash.

Literature on the "S" series will be gladly furnished, but the better way is to see and drive one of them yourself. You are always welcome at Case branch houses and factory display rooms.

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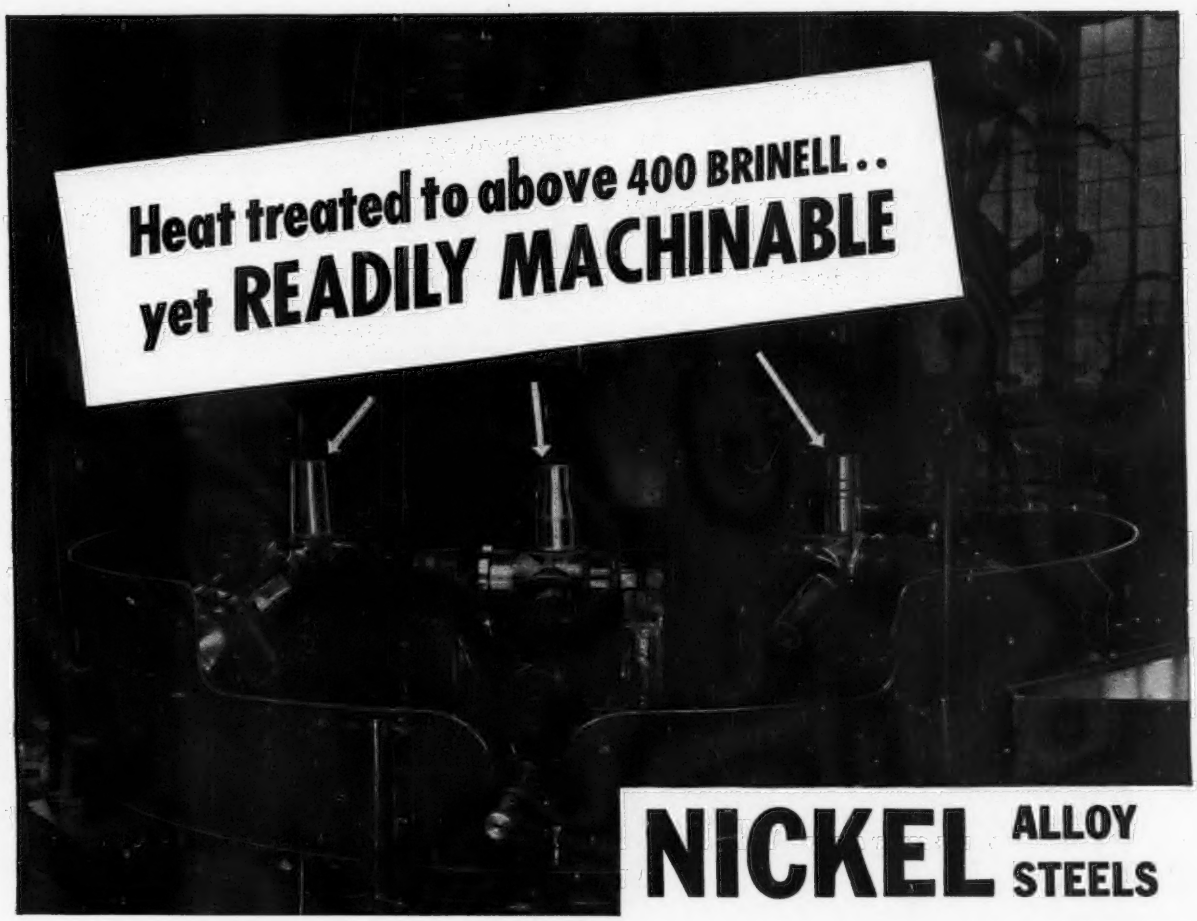


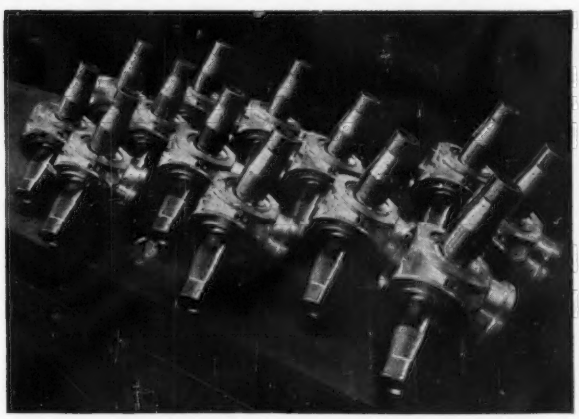
NICKEL ALLOY STEELS

For parts which must have high hardness to perform satisfactorily in service, heat treatment *before* machining can offer distinct advantages. Warpage and distortion resulting from heat treatment after machining cease to be an important factor. Straightening or other finishing operations to correct for such distortion are eliminated.

Especially interesting are present shop practices of airplane part and other mass production plants now machining heat treated Nickel alloy steels ranging in hardness up to 450 Brinell. *(above)* Stressed Hydromatic Propeller spiders of SAE 4340 heat treated to approximately 415 Brinell are machined with ease on a Bullard Mult-Au-Matic in the regular production line at the East Hartford, Conn. plant of Hamilton Standard Propellers, Division of United Aircraft Corp.

• • •

In a recent demonstration on a standard Warner & Swasey turret lathe conventional high speed tools readily turned, chamfered and drilled a 2″ bar of Nickel-chromium-molybdenum steel at a hardness of 450 Brinell. The turning cut was fed at .012″ at a speed of 42′ a minute. The close helical chip showed no tendency to tear, check or burn. The smooth surface produced indicates that machining Nickel alloy steels at high hardness is not unusually difficult.



Hamilton Standard Propellers, Division of United Aircraft Corp., East Hartford, Conn. regularly machine SAE 4340 stressed Hydromatic Propeller parts including spiders, illustrated here, and cams after they have been heat treated to approximately 415 Brinell. Hard Nickel alloy steels are no hazard where machining is concerned. For additional information please write to the address printed below:

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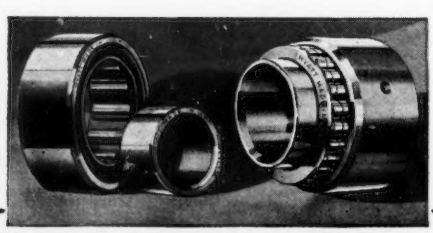

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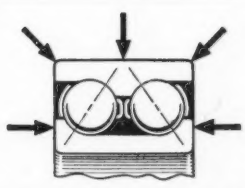

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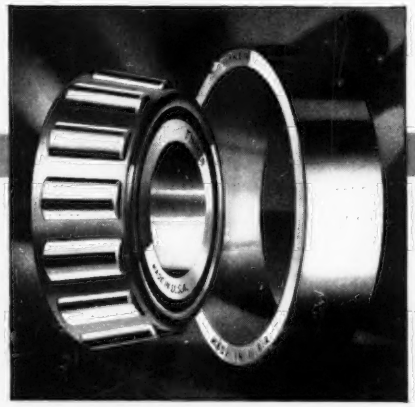

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